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BOMBS AND INFERNAL MACHINES.

THE word "bomb" must not be taken here in the restricted acceptation of a hollow projectile thrown by a piece of ordnance called a "mortar." It is an onomatopœia, implying the general sense of a receptacle filled with dangerous substances and capable of bursting with more or less noise under the action of a determinate internal or external movement. When solid substances of various kinds and sizes, designed to act after the manner of projectiles, are mingled with the charge, the bomb takes the name of "infernal machine." This latter is merely a variant of the bomb properly so called.

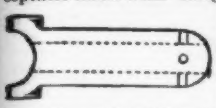


FIG. 1.—Fusee of a Hand Grenade of the Seventeenth Century.

Apparatus of this kind have been used at all periods, even before the epoch of the invention of detonating powder. For the envelopes of their primitive apparatus, the ancients ordinarily used pottery (*vasa fictilia*), oblong two-handled vessels called *amphoræ* earthen jugs (*fictiles lagenas*), pots (*ollas*) and every kind of earthen or glass vessel that satisfied the sole condition of being essentially fragile. We shall presently tell why such a condition was necessary.

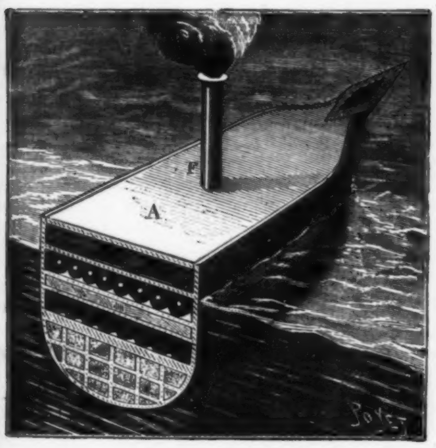


FIG. 2.—ST. MALO INFERNAL MACHINE.

A, elevation and section; B, bottom of hull filled with sand; C, main deck filled with twenty thousand pounds of powder with a foot of masonry above; D, lower deck with six hundred bombs and fire balls and two feet of masonry above; E, upper deck with fifty iron-hooped barrels filled with all sorts of explosive devices; F, chimney for setting fire to the powder and primers.

In the time of the Punic wars, the charge consisted of inflammable substances, such as pitch and resin or pitch and incandescent carbon. Eventually this charge was formed of Greek fire.

After the manner of Grecian and Roman antiquity, the middle ages likewise inclosed all sorts of things except incandescent substances in terra cotta or glass globes, but which were capable, nevertheless, of causing death through wounds, punctures, asphyxia, suffocation, or poisoning, or of merely exerting an irresistible repulsive action. Into them were put venomous serpents, juices of poisonous plants, metallic salts giving off mephitic vapors, animal substances in the process of putrefaction, and, as Siemienowicz says, an infinite number of other stinking and filthy materials. The Greeks of Byzantium introduced human excrement (*κόπρον ἀνθρωπείαν*) into them, and the natives of Liege, of the fifteenth century, did the same as the Greeks (*stercoribus injectis*). It is from this that come certain words of the vigorous military language—expressions *sui generis* that can scarcely be written in French or even in Latin.

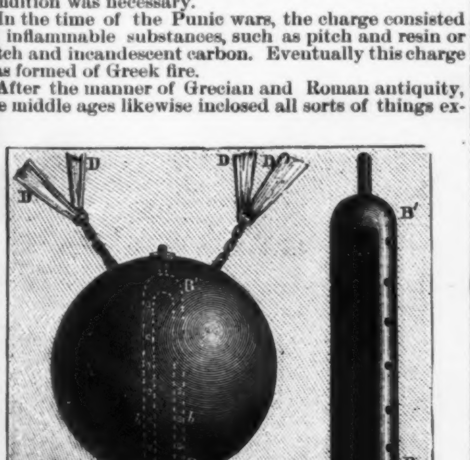


FIG. 3.—BLIND GRENADE.

A, charging aperture; B B, internal cylinder; C, barrels to fit into the latter; *m m*, flints; D D D D, slings for throwing the grenade; E, rod entering the cylinder, B; F, foot; *b b*, apertures to allow of the passage of the sparks produced by the friction of the flints.

As for the play of the deleterious or repugnant burning missile, that is very easy to understand.

The bomb was thrown either by hand or by means of a ballistic machine. At the instant of its fall, the fragile envelope, glass or terra cotta, broke and the charge was thus set at liberty. The fact of the discovery of gunpowder was rather of a nature to cause the fall into desuetude of these mediocre means of action, in which, however, must be recognized the merit of having put the pyrotechnic engineers in the way of the preparation of hollow projectiles containing an explosive discharge.

The first bomb that came from the laboratories of these engineers was the stink pot (*pot-au-feu*), which made its appearance as long ago as the beginning of the sixteenth century. The "pot" of this epoch consisted of a cylinder of glass or terra cotta filled with quicklime and granulated powder. An infernal machine was sometimes made of it by mingling a few pieces of iron with the powder. The firing was effected by means of a sulphured slow match.

The grenade, the invention of which also dates back to the first years of the reign of Francis I., was thus called by reason of its resemblance to the fruit of this name (*granatum*), called also Punic apple (*malum punicum*). It made its entrance upon the stage officially at the siege of Rouen, in 1562.

Now, remark that toward the end of the sixteenth century crime had already made its *debut* in the art of imitating the processes of the military art. In 1587 we find a Norman dispatching to a Parisian who had gravely offended him a box containing three tubes or gun barrels loaded for bursting, and so arranged as to go off at the precise moment of the opening of the box. The combination succeeded, the Parisian was killed and the Norman was condemned to the punishment of the wheel.

The seventeenth century witnessed the production of a host of pyrotechnic inventions, in the front rank of which it is well to place those of Jean Appier, called Hanzelet, "master of fireworks" of His Highness Charles IV., Duke of Lorraine. This emerited pyrotechnist recommended the use of the fire cask, the "most furious fire-vomiting machine in an assault," "partridges" and "rabbits" —"badly digesting game for those who taste it"— and a number of various other apparatus, "which, being properly contrived, are capable of cutting out disagreeable work for the enemy." Hanzelet also extolled the excellence of his firework box, an infernal machine mounted upon wheels, and that exploded as soon as it was touched. The firing was effected by means of a play of two "wheels that unclick" at the least motion of a strange hand. But observe a lofty spirit pervading western Europe. It was a question of doing things on a large scale. The effects produced by some little infernal machine no longer sufficed. What was necessary was a style of monster bomb capable of ruining important works of man's hand at one fell stroke.

Federico Giannibelli endeavored to destroy a bridge thrown over the Escaut, and, to this effect, constructed four large boats, each of which took aboard 7,700 pounds of powder, and in this charge he buried bullets, hooks, nails, and scrap iron.

In 1605, the mine prepared by the confederates of the powder conspiracy for blowing up Westminster consisted of thirty-six barrels, probably of about two hundred pounds each. According to the example given by such precedents, Louis XIV., in 1688, conceived the idea of ruining the port and city of Algiers through the bursting of a huge bomb filled with from seven to eight thousand pounds of powder.

It was natural that the Anglo-Dutch, implacable enemies of France, should, in their turn, imitate the great king, and this they did for more than a century. The infernal machine that they dispatched in 1693 against the port of St. Malo was a 300 ton bomb vessel, 34 ft. in length and 18 ft. in height, and drawing 9 ft. of water (Fig. 2). The main deck was filled with 20,000 pounds of powder, placed under solid masonry; the lower deck contained 600 bombs and fire balls, likewise inclosed in masonry; and the upper deck 50 barrels of firework embedded in a sort of concrete. Finally, the orlop was covered with 340 fire balls, grenades, bullets, chains, bits of metal, gun barrels with bursting charges, scrap iron, nails, etc. The interstices were filled in with combustible substances, and tarred canvas covered the whole. This huge floating bomb was towed leeward to the city. It had nearly reached the sea front of the enciente when a shifting breeze drove it off toward a rock, upon which it was observed to founder. The engineer who was steering it, seeing that it was sinking, hastened to set fire to it, and, of course, to desert it.

Although the explosion was effected far from the objective point, it produced a disastrous effect. A portion of the city was destroyed, and all the houses were shaken. The capstan of the galiot, weighing 2,000 pounds, was thrown over the ramparts and crushed a house upon which it fell. A part of the float did not blow up, and this fragment permitted of restoring the construction represented in Fig. 2.

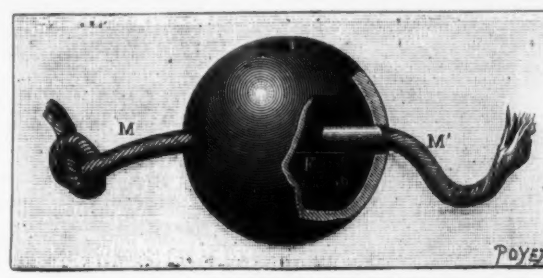


FIG. 4.—STATIONARY BOMB.

A, charging aperture; *m m'*, slow match; F, perforated tube.

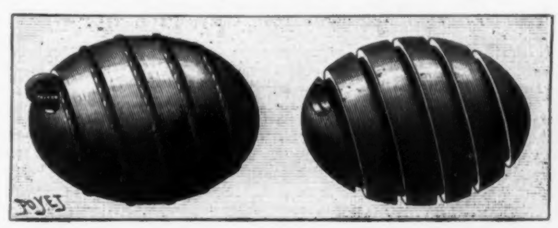


FIG. 5.—HEIMLICH OR LEG FEUER.

In spite of the excellence of the infernal machines of various models, the granade was to continue to be justly appreciated by military men. The value of this explosive being well recognized, Louis XIV. organized the "Grenadiers," at first to the number of four in the regiment of the "Fusiliers of the King." In 1672, this regiment comprised two battalions, each of twelve companies of fusiliers and one company of grenadiers. The men of the latter carried crosswise a *grenadière*, that is to say, a pouch containing their hand projectiles. A grenade of this epoch consisted of a small globe of bronze or iron filled with "pyric" (*pulvere pyrio*) or gunpowder or some other pyrotechnical composition. To its orifice was fitted a tube (fistula), which was filled with a composition that was slow-burning, lest the globe should burst in the hands of those who had to throw it. Fig. 1 shows a section of the fusee of a hand grenade of the middle of the seventeenth century. The pyrotechnists of the time called those grenades *blind* that had no "eye" to give passage to a slow match, and that were, consequently, thrown

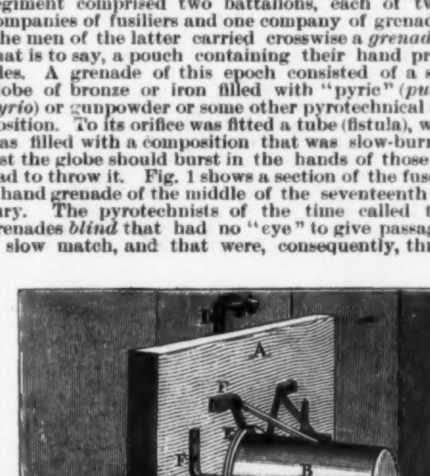


FIG. 6.—BRONZE PETARD.

A, plank to be applied against a door; B, petard attached to the latter; C, vent of the petard; D, hook for attaching the apparatus to a door; E, felt; F F F, petard braces.

without any match being lighted. "As soon as they touch the earth," says Siemienowicz, "or meet with any hard and fixed object, they promptly take fire and produce effects like other grenades." They were what we should to-day call explosive apparatus with percussion fuses.

Fig. 3 represents one of the types of "blind grenades" of this epoch. In addition to its charging aperture, it has two diametrically opposite orifices. The top one was tapped so as to receive the screw of an iron plate cylinder provided with apertures, and "all chased on the inside; that is to say, as rough and as sharp as a file." The author means to speak of a rugosity into which entered a system of two small barrels mounted upon a rod that was introduced with slight friction through the lower orifice. This rod itself terminated beneath in a foot, upon which, by reason of preponderance, the thrown bomb always fell. What then happened? The author will tell us: "As soon as the grenade falls upon this wide and flat foot, the barrels inclosed in the cylinder are forced, through the weight of the said grenade, to ascend, and, consequently, the flints, rubbing harshly against the internal furrows of the cylinder, never fail, through this violent collision, to strike fire, which, immediately insinuating itself through the apertures in the cylinder, communicates with the powder inclosed in the grenade. By this means, it will cause it to produce the same effect as if it had been prepared in another manner."

Let us rapidly review a few other arrangements of the engineers of this time, which was so fecund in pyro technical inventions.

The stationary bomb, to be laid mysteriously in a determinate place, consisted of a metallic sphere of a diameter usually greater than that of the hand grenade (Fig. 4). In addition to its charging aperture, it was provided with two diametrically opposite orifices through which passed a wooden or metallic tube. This tube, furnished with a number of small apertures, was strewed within with very finely comminuted powder, and gave passage to a slow match that was lighted at one end. "It is possible," says Siemienowicz, "to conceal this bomb at the entrance of an avenue or in some other defile through which we shall hope that our enemy is to infallibly pass."

The German engineers of the seventeenth century applied the name of *heimlich* or *leg feuer* to certain pyrotechnical apparatus that were "clandestine," that is to say, that could be "concealed in some secret place, in order to cause them to produce their effects at a certain determinate time." These well dissimulated apparatus were laid "in houses, barns, granaries and similar places; in magazines and arsenals; and finally, in wagons, chests and casks, and such luggage as one may have to carry into the cities and fortresses of the enemy."

Here we have a prototype of the occult apparatus employed in our time for the crime commonly called bomb throwing.

Siemienowicz has left us a description of various types of this weapon. In Fig. 5 we have one whose ovoid wooden shell is "channeled spirally from bottom to top, so that in this spiral groove there may be adjusted and glued a match that passes and winds from one end to the other. This spiral match should be one of those that neither smoke nor stink. Its length is determined by the space of time at the end of which it is necessary that the globe shall produce its effect." As for the charge of this *timed* explosive, that consisted of "violent substances," such as the one of which Brechtel has given the following formula: "Take three parts of gunpowder and one part of sulphur, pulverize the two elements into a very subtile powder, and then incorporate them. Afterward add a little resin and a few drops of turpentine, and then knead all this with linseed oil and alcohol. After well mixing, fill your globe with this composition."

"The petard," says Father Daniel, in his 'History of the French Militia,' "is a sort of small mortar which is loaded with the finest kind of gunpowder (Fig. 6). This powder is covered with felt and the latter with a wooden disk. This species of cartridge is driven in by giving it seven or eight blows of the mallet, so as to compress the powder, without, however, granulating it in the least. The rest of the petard is filled with yellow wax and black resin, and the whole is covered with cere-cloth. The petard, at the muzzle end, is set into a thick piece of plank, and the latter is placed against and hooked to the door that it is desired to shatter. Then fire is applied to a small match that passes through the vent in the breech of the petard. The match having communicated fire to the powder, the petard produces its effect upon the door throughout the entire width of the plank and shivers it." This apparatus, called also a *pyloclaste* or "door breaker," was in great demand as long ago as the end of the sixteenth century, after Henry of Navarre had successfully employed it at Cahors in 1579. It was ultimately replaced by the wooden petard of the artillery service, which, in turn, was dethroned by the dynamite petard.

The last year of the eighteenth century witnessed a crime that immediately made a prolonged echo throughout Europe. We refer to the explosion of Saint Nicaise Street of the 24th of December, 1800. The infernal machine in question consisted of a water carrier's cask filled with powder and scrap iron, and placed upon a cart drawn by a pony. The igniter was a gun hammer actuated by a lanyard that one of the conspirators had taken upon himself to pull.

During the course of his expeditions in Africa, Marshal Bugeaud sometimes employed analogous methods. When, in beating a retreat, he was too closely pressed by the Arabs in scattered order, he had a goodly number of cracker boxes stowed here and there back of his column. Now, the natives well knew the form of these special boxes and were very fond of their contents—the *galleta roumia*. They, therefore, made a scramble for the booty that was offered them, and set free the exploding mechanism. The explosion immediately evoked a concert of savage yells, for (is it necessary to tell it?) instead of crackers, the boxes contained a charge of powder, . . . and the Arabs found this charge very bad.

The use of small mines thus arranged in the open air or buried so as to be on a level with the surface of the earth is reglementary in modern armies, wherein they are designated by the generic name of "fougades."

In order to arrange an ordinary fougade by rule, there is dug a small well, AB, which is connected by a trench, BC, with the point where the operator is to stand whose business it is to do the firing (Fig. 7, No. 3). The powder box, A, is placed at the bottom and at one of the sides of the well. The trench allows of the passage of the conductor or the firing line. Things being thus prepared, the well and trench are filled in and the firing is effected at will at the moment that appears opportune.

But an ordinary fougade, a dry torpedo buried at a slight depth, is of a nature to be easily fired automatically; in other words, the explosion may be produced either through a fulminating primer or through the production of an electric current at the precise moment at which a man plants his foot upon its ground plate.

In the first case, the fougade or torpedo is provided with a detonating primer which is actuated by a plate, MN, arranged flush with the surface and covered only with a few inches' thickness of earth (Fig. 7, No. 1). When the plate tilts under the weight of men who are passing, the friction piece of the primer, B, is pulled by the cord, C, fixed to the plate, and causes the detonation of the fulminate.

In the second case an electric primer, D, is placed in the charge, C, and, of the two conductors, one is in constant communication with a battery (Fig. 7, No. 2). The other communicates with the latter only through the intermedium of the plate, which, in ordinary times, is kept raised by means of a spring. The circuit is then interrupted, but, as soon as a shock depresses the plate, and consequently the upright, AB, the circuit is closed and an explosion is produced.

In 1870, the defenders of Paris arranged bombs of this kind behind the glacis of the enceinte. On the 22d of August, 1877, the Russians brought similar ones into play, and not without success, in the celebrated pass of Schipka.

The fougade or bomb torpedo is nothing more than a copy of the *ty-lei*, or "earth-thunder," that has been in use in China since a period previous to the Christian era. The apparatus of this kind consists of four bombs of the same caliber inclosed in a wooden box, D, divided into two parts, B and C, by a horizontal partition (Fig. 7, No. 4).

In the upper compartment, B, are arranged the projectiles, the aperture downward and the fusee passing through the partition. In the lower compartment is placed the charge of powder, in which are buried the extremities, AA, of the apparatus that transmits fire. Thus prepared, the box is buried in the earth, flush with the surface, after the manner of the powder box of an ordinary fougade.

Instead of using boxes, bombs simply buried flush with the surface may be brought into play. Such projectiles are grouped according to lines determined by local circumstances. *Chapelets* is the name given to a series of bombs connected with each other by one firing match in common or by the same electrical conductor. The defenders of Badajoz (1812) used to advantage this method of resistance to the efforts of a resolute besieger.

But here intervenes a discovery fecund in results as violent as unexpected, and which suddenly produces in the processes of the pyrotechnic art a revolution comparable to that which the invention of powder did of old. We refer to the putting of shattering explosives into service.

It was thirty-six years ago that shattering materials inclosed in metallic envelopes and acting after the

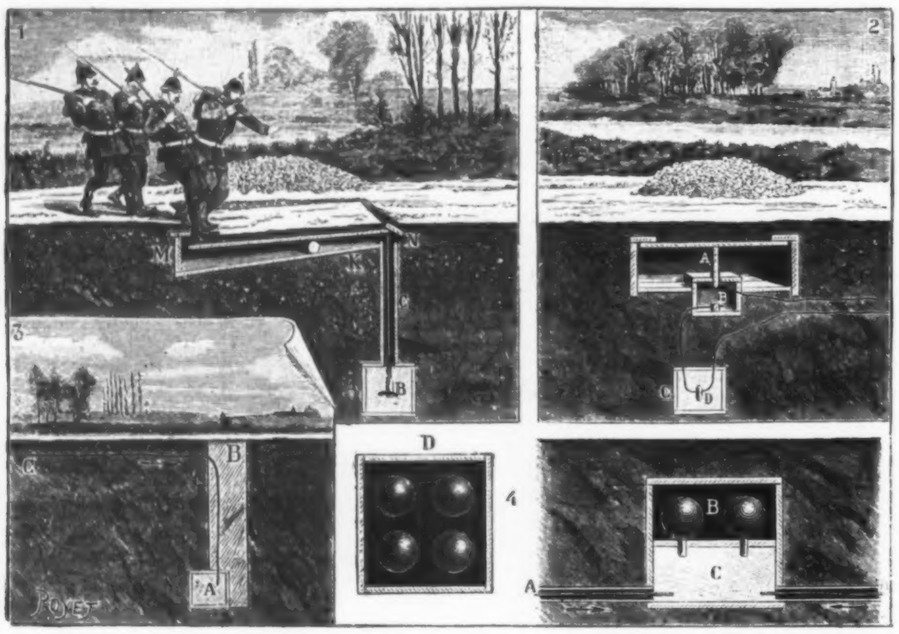


FIG. 7.—FOUGADES OR DRY TORPEDOES.

1. Automatically exploding fougade. 2. Electric automatic torpedo. 3. Ordinary fougade: A, powder box; B, well; A B C, exploding conductor. 4. Bomb fougade: B C, box with two compartments for bombs and powder; D, plan of the box.

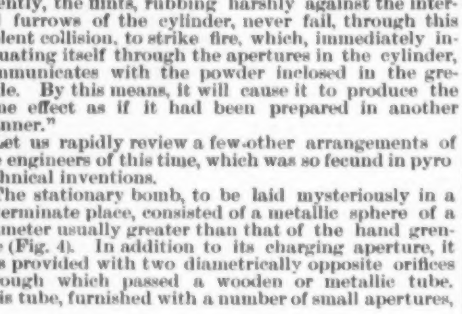


FIG. 8.—RING BOMB (×½).

Plan and section through M N. Curved tube containing an explosive surrounding very fragile glass tubes filled with a liquid that becomes disseminated through the charge and causes its explosion.

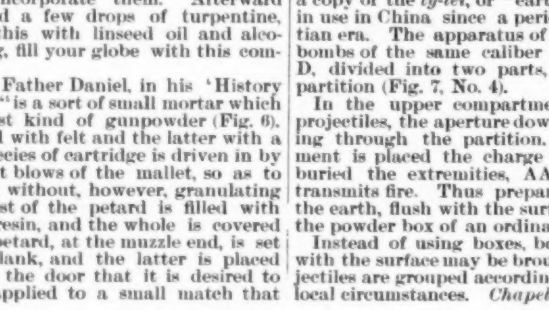


FIG. 9.—THE ORSINIAN.

A A, percussion cap nipples; B B, charging apertures; C, lug serving to throw the projectile.

manner of shells fired by guns were used for the first time. This event dates back to the day of the crime of Orsini, Pierri, Di Rudio and Gomey (January 14, 1858). On that day, terrible hand bombs, it will be remembered, mowed down the imperial escort at the foot of the staircase of the old Opera House, situated on Le Peletier Street. The apparatus thrown by Orsini and his accomplices were of three different styles. The covering of the first was formed of a hollow cast iron cylinder 3¼ inches in length and 2¾ in external diameter. It consisted of two parts connected by a screw thread, and was charged with fulminate of mercury and provided at the surface with twenty-two percussion cap nipples so arranged as to assure an explosion at the moment of the fall of the weapon. The second model differed from the first only in the cylinder being provided with hemispherical caps. The third was in the form of a sphere.

In 1870, General de Riviere, having been ordered to proceed to the putting of the place of Lyons in a state of defense, charged some cylindrical grenades, tipped with hemispheres, with disruptive materials. These hand projectiles, prepared by a pyrotechnist of Rive-de-Gier, and duly tried in the interior of an open well back of the fort of Montessuy, were designed to be thrown upon assaulting columns. No occasion occurred to use them at Lyons, but they were employed at Paris at the time of what is called the insurrection of the "Commune," especially at the time of the attack, by the regular troops, of the "Park of Birds," situated between Issy Park and the fortified enciente. It was by throwing these grenades over the coping of a battlemented wall that did us a great injury that it was possible for us to clean the foot of this defensive wall in the interior. After the entrance of our soldiers into Paris, the direction of the throwing service of these torpedo grenades was intrusted to an officer of miners. These hand projectiles produced formidable effects. The first one that was thrown fell into the shop of a milliner, whose elegant furniture was literally pulverized. But the insurgents of the Commune had these torpedo grenades likewise, and even two models of them. The first, which was of cast iron, had the form of a hollow ring of from 4 to 5 inches diameter (Fig. 8), and contained two small curved, very thin glass tubes that could not fail to break at the first shock, that is to say, at the moment of the projectile's fall. The liquid set free then caused the explosive charge to detonate, and the brittle metallic envelope instantaneously flew into pieces.

The second, called the "Orsinian" (Fig. 9), consisted of a small sphere of brittle zinc weighing about ten ounces. This sphere was hollow. Its external diameter was scarcely two inches and its thickness but about a quarter of an inch. The charge was introduced by two diametrically opposite apertures that were closed by means of plugs after the operation of charging. The apparatus was studded with percussion cap nipples inserted in the summits of regular pentagons inscribed in two parallels taken on each side of the equator at the distance of about half an inch. At a point in this circle there was a lug cast in a piece with the sphere and containing an aperture for the reception of the cord by means of which the projectile was thrown forward. The explosion was produced by the fall of the sphere.

As we have before said, then, the advent of explosives has singularly revolutionized the methods of certain branches of the military art.

We shall refrain from entering into further details concerning the new principles that preside over the execution of campaign torpedo works, and the reason for such desired reticence will be understood. It is because crime is everywhere always on the watch and ready to seize and appropriate to itself the means of action which the artillery and engineering services have at present at their disposal.—*Lieut.-Col. Hennebert, in La Nature.*

[Continued from SUPPLEMENT, No. 964, page 15403.]

THE RELATION OF MATHEMATICS TO ENGINEERING.*

SUBMARINE telegraphy yields some interesting examples of the application of the higher mathematics. When a cable across the Atlantic was first seriously entertained, the first point to be settled was how many words a minute could be sent through such a cable. This was the most practical question possible. Upon the answer depended the prospect of the cable paying commercially, if successfully laid. The matter was dealt with by Prof. Thomson,† of Glasgow, now Lord Kelvin. He showed that the propagation of an electric disturbance in a cable could be expressed by a partial differential equation, and that the solution of this equation under certain conditions applicable to practice could be expressed either by a definite integral or by a infinite series. The values of these were calculated, and hence before an Atlantic cable was laid at all it was known how long it would take a signal to reach the opposite shore, and how much its intensity would be diminished in transmission. Referring to Fig. 5, abscissæ represent time, reckoned from the time of making contact at the sending end of the cable, ordinates the currents at the receiving ends, curve (1) gives these currents when the contact at the receiving end, after being made, is continuously maintained.

It will be observed that for a time, a, there is hardly any current at the receiving end, that then the current rapidly increases and attains to half its final value after a time equal to about $5a$. Curves (1) . . . . (7) show the currents at the receiving ends when the contact is made at the sending end maintained for times a, $2a$, . . . $7a$ respectively, and then broken. Looking at curve (1) one sees how small is the amount of current and how long it lasts compared with the time during which contact is made. The time, a, depends on the length and character of the cable; it is equal to

$$k\,c\,l^2 \log_e \frac{4}{3} / \pi^2,$$ where k is the resistance per unit length, c the capacity per unit length, and l the length of the cable. The knowledge of what is the commercial value of a cable depends on a knowledge of the value of a, and this cannot be obtained without knowing the differential equation $c\,k\frac{dv}{dt} = \frac{d^2v}{dx^2}$,* to which I have referred, and its by no means simple solution either as a definite integral or as an infinite series. So far as I know, this piece of higher mathematics cannot be evaded by any mere elementary treatment. The transmission of disturbance in a cable is quite different from the transmission of sound waves in air, which move with constant velocity. If the cable be doubled in length, it takes four times as long for the signal to pass through it instead of just twice as long, as would be the case if it were a proper wave motion. In fact, the time of passage between the making of contact at the sending end of the cable and the beginning of the resulting disturbance at the receiving end varies as the square of the length of the cable. The mathematical theory is exactly the same as that of the transmission of heat in a plate, one surface of which is suddenly exposed to a temperature different to the temperature of the plate.

This is constantly occurring in the application of mathematics—one piece of mathematical work serves for many physical problems having apparently little in common. Fourier long ago discussed the heat problem, little dreaming that his analysis would be just what was wanted for ascertaining how fast signals could be sent across the Atlantic by a system of telegraphy which in his days had not even been projected in its simplest form. The same differential equation also gives the theory of the transmission of telephonic messages through cables; but the solution is then easier, and tells us exactly why it is so much more difficult to speak through 100 miles of cable than through the current and on the size of the conductor. In the case of a cylindrical conductor the solution involves a knowledge of Bessel's functions. We learn that if the current has a high frequency, or if the conductor be large, there will be very little current in the center of the cylinder, and that, therefore, for any practical purpose the center of the cylinder might just as well not be there; the current is largely confined to the part of the conductor near to its surface. The currents at different depths in the conductor attain to their maximum values at different times; those near the surface of the cylinder occur before those at some distance from the surface.

The mathematical conditions are expressed by the same equation as is used to express the disposition of heat in a cylinder the surface of which is submitted to a periodic variation of temperature. Any one who had thoroughly mastered the heat problem would be quite prepared to deal with the problem of currents in a conductor. It cannot be too often repeated, any piece of pure mathematics which finds one application to a physical problem is almost sure to find, in exactly the same form, applications to other problems which superficially are absolutely distinct. The differential equation in this case is $k\,c\frac{dv}{dt} = \left(\frac{d^2v}{dr^2} + \frac{1}{r}\frac{dv}{dr}\right)$, the similarity of physical condition to the problem of linear propagation of heat is close, but the mathematics differ materially, owing to the presence of the term $\frac{1}{r}\frac{dv}{dr}$ in the equation. Mathematics deals with the relation of quantities to each other without troubling as to what

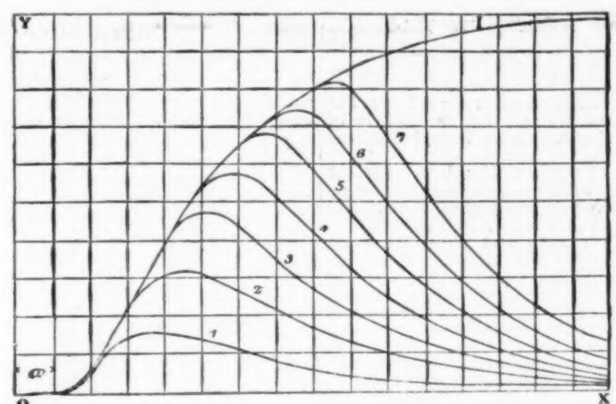


FIG. 5.

1,000 miles of overhead line. As I have just stated, the differential equation of the disturbance in the cable is $c\,k\frac{dv}{dt} = \frac{d^2v}{dx^2}$. A musical note of period T spoken into the cable through a telephone is properly represented by $A \sin \frac{2\pi t}{T}$; the disturbance in the cable will be

$$v = A\,e^{-x\sqrt{k\,c\pi/T}} \sin\left(\frac{2\pi t}{T} - x\sqrt{k\,c\,\pi/T}\right)$$

as may be easily verified by differentiating. This equation tells us everything. It tells us the rate at which the waves diminish with the distance. This rate increases with the resistance, with the capacity and with the frequency. If the capacity is at all considerable, the diminution is rapid. The velocity of the waves is not the same for all frequencies, as is the case with waves in air, but varies as the square root of the period, so that if two notes were sounded, the high note would arrive after the low notes, and the resultant effect would be entirely destroyed. Here, again, it is difficult to see how the differential equation and its solution can be evaded.

Though the history of the telegraph dates only from a little more than fifty years ago, it is ancient in comparison with the other great applications of electrical science, which have received their development during the last fifteen years. Here again mathematics which are not quite elementary have played their part. In the theory of transformers we find another illustration of the need of knowing how formulæ are obtained if they are to be correctly applied. The early transformers were made with unclosed magnetic circuits; there was an iron core, but the lines of magnetic force passed through air for a considerable part of their path. In this case a complete mathematical theory was not very difficult. But speedily closed magnetic circuits were found to be better, and the relation of magnetic induction and magnetic force became all-important. If any one were to apply mathematical formulæ which were true for the earlier transformers to the later ones, his results would be inaccurate. Indeed, a wholly different method of attack on the problem was needed, taking account of the facts as they are, and not applying results which were true of older apparatus to cases essentially distinct.†

The employment of alternating currents has brought into use, as a necessity for understanding the actually observed phenomena, a great deal of mathematics. Why is the apparent resistance of a conductor greater for an alternating current than for a direct current? And by resistance I do not mean the quasi-resistance due to self-induction.‡ The mathematical electrical theory is ready with an answer; it is ready, too, to tell us how the difference depends upon the frequency of the physical meaning of the quantities may be. Hence it is that the mathematical treatment of two such problems as the distribution of currents in a cylindrical conductor and of heat in a cylinder is identical, whereas the treatment of the distribution of heat in a cylinder is quite distinct from the treatment of the distribution of heat in a sphere or in a solid bounded by two parallel planes.

A curious phenomenon was observed in the large alternate-current machines at Deptford when connected to the long cables intended to take the current to London. The pressure at the machines when connected to the conductors was, under certain conditions, actually greater than when not so connected. The phenomenon is one of resonance very analogous to the heavy rolling of ships when the natural period of roll is about the same as the period of the waves.* The period of the alternating current corresponds to the period of the waves, the self-induction of the machine to the moment of inertia of the ship, the reciprocal of the capacity to the stiffness of the ship, and the electrical resistance of the conductors to the frictional resistance to rolling. The mathematics in the two cases is then the same. The effect was predicted long before it was observed in a form calculated to cause trouble.

A problem which is still agitating electrical engineers is that of running more than one alternate-circuit dynamo machine connected to the same system of mains. Before the matter became one of practical concern, it was considered in this room, and it was shown mathematically that it was possible to run independently driven alternators in parallel but impossible to run them in series. That is to say, that if two alternators were connected to the same mains, they would tend to adjust themselves in relation to each other so that their currents could be added, but that if an attempt were made to couple them, so that their pressures should be added, they would adjust themselves so that their effects would be opposed.†

Perhaps of all engineering problems which have received their solution in the last hundred years that of the greatest practical importance is the conversion of the energy of heat into the energy of visible mechanical motion. The science of thermodynamics has advanced along with the practical improvement of the steam engine. By its aid, particularly by the aid of the so-called second law, we know what is possible of attainment by the engineer under given conditions of temperature. I must not trench on the subject of one of my successors, but I may point out that our knowledge of the second law of thermodynamics was first developed by means of mathematics, and that to-day its neatest expression is by means of partial differential coefficients. The two most notable names in connection with the development of the second law of thermodynamics in harmony with the first are those of Kelvin and Clausius; both dealt with the subject in a mathematical form not comprehensible to those who have not had substantial mathematical training.

Illustrations such as these might be multiplied almost indefinitely. They show that the advancement

* The "James Forrest" lecture, delivered at the Institution of Civil Engineers, by Dr. John Hopkinson, F.R.S., on May 3, 1894.—*Nature.*

† "Mathematical and Physical Papers," vol. ii., p. 61. Sir W. Thomson.

* v is the potential, t the time, and x the distance from the sending end of the cable.

† *Proceedings* of Royal Society, February 17, 1887.

‡ Lord Rayleigh, *Phil. Mag.*, vol. xxi., p. 381.

* Institution of Electrical Engineers, November 13, 1884.

† Minutes of *Proceedings* Inst. C.E., April 5, 1883; Institution of Electrical Engineers, November 13, 1884.

of the science of engineering has been aided in no inconsiderable measure by the labors of mathematicians directly applying the higher mathematical methods to engineering problems. They show, too, one way in which respect for a formula may be dangerous, one way in which it is true that mathematics may be a bad master. In St. Venant's problems we have an example in which the use of older results of limited application in cases where the assumptions on which they rest are not true will mislead. The examples show the proper remedy; it is a more complete application of mathematical methods. The error is just one which a man will make who has the power to use a formula without a ready understanding of how it is arrived at. A practical man, ignoring mathematical results, might or might not escape the error of supposing that a triangular shaft would break at the angles under torsion; the half-educated mathematician would certainly fall into the snare from which complete mathematical knowledge would deliver him. You can only secure the services of that good servant, mathematics, and escape the tyranny of a bad master, by thoroughly mastering the branches of mathematics you use. The mistake caused by the wrong application of mathematical formulæ is only to be cured by a more abundant supply of more powerful mathematics.

There is another drawback to the use of results, taken, it may be, out of an engineering pocketbook by those who are not prepared to understand how they are reached and on what foundations they rest. The educational advantage is lost. The close observation which enabled the earlier engineers to proportion their means to the ends to be attained was no doubt very laborious, and the results could not be applied to cases much different from those which had been previously seen, but the effect on the character of the engineer was great. In like manner, to thoroughly understand the theory of an engineering problem makes a man able to understand other problems, and in addition to this precisely the same mathematical reasoning applies to many cases. The mere unintelligent use of a formula loses all this; it leaves the mind of the user unimproved, and it gives no help in dealing with questions similar in form, though different in substance.

But even the use of mathematics by competent mathematicians is not without drawbacks. Mathematical treatment of any problem is always analytical—analytical, I mean, in this sense, that attention is concentrated on certain facts, and other facts are neglected for the moment. For example, in dealing with the thermodynamics of a steam engine, one dismisses from consideration very vital points essential to the successful working of the engine, questions of strength of parts, lubrication, convenience for repairs. But if an engineer is to succeed, he must not fail to consider every element necessary to success; he must have a practical instinct which will tell him whether the instrument as a whole will succeed. His mind must not be only analytical, or he will be in danger of solving bits of the problems which his work presents, and of falling into fatal mistakes on points which he has omitted to consider, and which the plainest, intelligent practical man would avoid almost without knowing it.

Again, the powers of the strongest mathematician being limited, there is constant temptation to fit the facts to suit the mathematics, and to assume that the conclusions will have greater accuracy than the premises from which they are deduced. This is a trouble one meets with in other applications of mathematics to experimental science. In order to make the subject amenable to treatment, one finds, for example, in the science of magnetism, that it is boldly assumed that the magnetization of magnetizable material is proportional to the magnetizing force, and the ratio has a name given to it, and conclusions are drawn from the assumption, but the fact is, no such proportionality exists, and all conclusions resulting from the assumption are so far invalid. Wherever possible, mathematical deductions should be frequently verified by reference to observation or experiment, for the very simple reason that they are only deductions, and the premises from which the deductions are made may be inaccurate or may be incomplete. We must always remember that we cannot get more out of the mathematical mill than we put into it, though we may get it in a form infinitely more useful for our purpose.

Engineers no doubt regard their profession from very different points of view; some think it a mere means of making money; some regard it as an instrumentality for benefiting the race; while others again delight in it as an interest in itself, and delight in it most of all when new knowledge is added to that which we know already. It is just the same with the medical profession; some attend patients for the guineas they receive, some give a very high place to motives of benevolence, while others love it as a field where new knowledge may be found and the delight of discovery enjoyed. In regard to the first class of engineers, I have no doubt a little skill in managing a board of directors or impressing a committee of Parliament will be much more useful to the engineer than a great deal of mathematics. Let him manage his board and buy his mathematician, and it is very probable he will make much more money than the mathematician or any other person of skill whom he may employ. But we cannot all of us make money in this way. In the future it is likely that educated men will have to work harder and receive less, and it is a great thing if their work can be made itself a joy, and surely this can best be by a thorough understanding of the reason of all they do by the feeling that they have full competence to form their own judgments without depending much on the authority of others. This can only be, in the words of Sir John Herschel, by a "sound and sufficient knowledge of mathematics, the great instrument of all exact inquiry, without which no man can ever make such advance in any of the higher departments of science as can entitle him to form an independent opinion on any subject of discussion within their range."

After all, in any department of applied or pure science the highest satisfaction comes from accomplishing that which no one has done before, from disclosing what no one hitherto has known. If a department of the arts or sciences ceases to advance and becomes simply the application in known ways of known principles to obtain known ends, that department has lost its charm till the time comes for a fresh advent of change and development. To effect such advances it is easy to show that mathematics is a most necessary instrument. Here it is no drawback that the mind of the discoverer is too analytical; he may deal at his pleasure with one aspect of a problem, and it does not detract in any way from the value of his solution that he does not touch on incidental matters. Some of you who love the interest of continual advance in our science and practice may look forward with a shade of sadness to a possible time when all is done or known which can be done or known, and the work of the engineer shall be merely applying principles discovered by his predecessors. In such a state, when the experience of the older generations shall control the practice of to-day, the free use of mathematical methods may be effectually superseded by the application according to rule of mathematical formulæ. But it would be a much less interesting condition than the constant change of to-day, when the practical experience of ten years ago is in many departments rendered worthless by later discoveries. But we need not fear that such a time of petrifaction will come so long as, while reverencing the discoverers who have added to our knowledge, we endeavor to replace their methods by better, and expect that those who come after us will, in their time, improve upon ours. Our knowledge must always be limited, but the knowable is limitless. The greater the sphere of our knowledge, the greater the surface of contact with our infinite ignorance.

[Continued from SUPPLEMENT, No. 964, page 15405.]

NICKEL—ITS HISTORY, USES, AND DISTRIBUTION.*

By A. G. CHARLETON, A.R.S.M.

I HAVE here some interesting geological sections, copied after Levat, describing the features that have been mentioned. Deposits closely approaching in

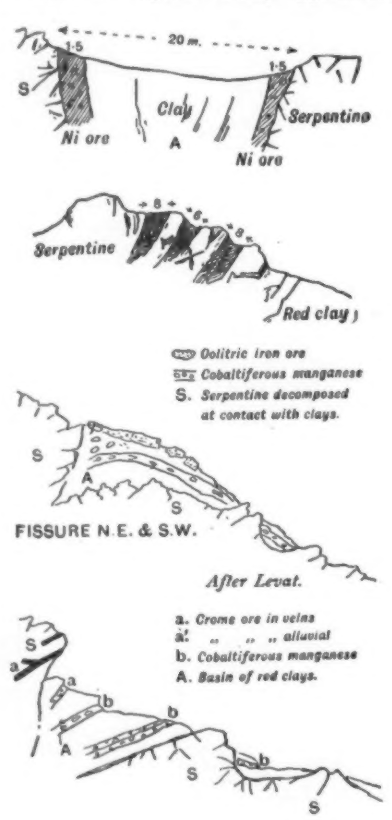


FIG. 2.—NEW CALEDONIA DEPOSITS.

type those just described were discovered in 1881, at Riddles, Douglas Co., Oregon, and others of a similar kind have been found at Webster, North Carolina. The Riddles deposits all lie at or near the surface, in beds 4 to 30 feet thick, occurring as a bowlder formation, scattered through a ferruginous earth or in beds underlaid by serpentine, and associated with chrome iron.

F. W. Clarke, *American Journal of Science*, vol. xxxv., p. 483, gives a typical series of analyses, which show that the relative composition of silicate minerals obtained from New Caladonia, Oregon, and North Carolina agree very closely in composition and appearance. A fresh specimen of "country" was analyzed from Oregon, and some olivine was found in it. The rock contained 0·10 per cent. NiO, the olivine 0·26 per cent. NiO.

This suggested to Clarke a probable source of derivation of the nickel in the altered beds of ore, and the microscopical investigations of Diller confirm his view. He considers the Riddles rock as belonging to the peridotes. It is a holocrystalline, granular rock, composed essentially of olivine, while one-third of the rock mass consists of enstatite, with a small percentage of chromium and magnetite. Quartz is present from metasomatic change, and whenever genthite appears it is always associated with quartz or serpentine. The genthite occurs in the serpentine, directly connected with the grains of olivine, from which the serpentine has been derived, and Diller states there is every reason to think the genthite is primarily derived from the same source. Though the Webster rock (which is also a peridote, of the variety known as dunite) contains less enstatite, and the nickel silicates are not so closely intermixed with quartz, the relation of the genthite to the serpentine and olivine is the same as at Riddles. Of the New Caledonia genthite, Diller says, like that of Oregon, it is disposed in layers and cavities, thoroughly intermingled with quartz, and sections show the serpentine with traces of olivine and enstatite so disposed as clearly to indicate that the serpentine naumeite, and other secondary products, have resulted from the alteration of the peridote rock.

According to S. H. Emmons (*American Mining Journal*, April 30, 1892), the nickel deposits of North Carolina are found in veins of three distinct classes—1, those occupying fissures, the strike of which is more or less normal to the planes of division, that give a bedded aspect to the chrysolite rock mass, and there are numerous counter veins, with a strike oblique to the first series; 3d, there are bedded veins, located in planes of division. He is of opinion that the counter and bedded veins will not be found very productive, and the first series will alone yield any considerable supply of ore.

A nickel iron josephinite has been lately discovered, in the form of pebbles and smooth bowlders, in considerable abundance in the placer gravels of a stream in Josephine County, Oregon. They are supposed to have been derived from some dike of ultra-basic rock.

Melville has described this alloy (*American Journal of Science*, vol. xliii., p. 509), which is highly magnetic. The pebbles are a greenish black, with bright areas of a grayish metal. The greenish black portion consists of silicates, some of which are indissoluble in HCl. Nickel is found in the Urals at Rewdinsk, in veins six feet wide, between chloritic schist and serpentine, as well as in a great many places in other parts of the world. At the Kelsey Mine, Los Angeles Co., California, Ni and Co ores are found in the comparatively rare form of arsenates, together with silver glance and native silver, in a fissure vein in close relation with a diorite dike. The assorted ore contains 7 per cent. to 15 per cent. cobalt, 2 to 3 per cent. nickel, and 1,000 to 1,400 oz. of silver per ton. Rich nickel ore has also been found in the Gem Mine, Fremont Co., Colorado, in a hornblende schist occurring as an arsenide and sulphoarsenide, some of the specimens being so permeated with fine wire silver as to be difficult to break. At surface the ores were mostly copper, but at a depth of 15 to 20 feet nickel was struck, and continued down to 75 feet, when the vein, which had averaged 3½ to 4 feet, cut out and appeared to be lost, but on resuming sinking, a streak of ore about 18 inches wide was struck containing the same minerals and supposed to be a continuation of it, though this has not been definitely proved. Small shipments of this ore ran from 12 to 34 per cent. nickel and 2 to 4 per cent. cobalt; the last lot shipped to England contained most of the nickel as niccolite. The ore streak is unfortunately narrow, the walls hard, and the ore difficult and expensive to mine. Nickel is known to exist in the hornblendic rock near Salida, Colorado. The serpentines of the west of Ireland and Cornwall, and indeed almost all serpentines, contain a little nickel, and it is met with in Australia, New Zealand, and South Africa. Sufficient has therefore been said to show that nickel ores are widely distributed over the world, though in the present condition of our metallurgical knowledge of the subject payable deposits are less numerous than those of most of the common metals.

THE GENESIS OF NICKEL.

To explain the genesis of this class of ore deposits one must glance for a moment at the sources from whence nickel is derived. Native nickel is found alloyed with iron in meteorites, and also in some ultra-basic lavas, while the spectroscope reveals its presence in the solar atmosphere. It is showered on the surface of our planet in the form of meteorites, those fiery messengers telling of the wreck of other worlds, and testifying to the common origin of the material universe, in the form of 1, holesiderites, composed entirely of nickel iron; 2, syssiderites, the nickel iron of which contains silicates of magnesia and iron protoxide, identical with olivine, and at other times a mineral resembling augite; 3, sporadosiderites, the most common kind, usually crystalline in space, and containing nickel iron, troilite, chrome iron, w. titanic and phosphoric acids; 4, asiderites, distinguished by the presence of hydrocarbons in which nickel is present as an oxide. Some of them have been shown to contain pyroxine and feldspars (chiefly anorthite) and the absence of quartz and highly silicated feldspars is to be noted. These four classes of meteorites show a gradation from almost pure metal containing over 98 per cent. of nickel iron to a stony mass closely resembling some basic lavas.

Now, according to the last determinations of Mons. Alphonse Berget (*Comptes Rendus*, July, 1893), the density of the earth is about 5·41, while, so far as our limited observation extends, that of the crust is about 2·5. Various theories have been advanced to account for this, and some very first-rate authorities have suggested that the heavier metallic elements might possibly be found to predominate in the nucleus, basing their views on widely extended observation of past and present volcanic phenomena.

It has been found that once the acid stage is past, lavas become more basic, and while each succeeding flow from any one vent might not be more basic than the preceding one, yet the tendency is in that direction till, finally, ultra-basic lavas are extruded from the centers of intense and long continued activity. This average order invariably, I believe, holds good everywhere over the earth's surface, provided the volcanic force is long enough active. The ultra-basic

* A paper recently read before the Society of Arts.—*From the Journal.*

rocks have in composition many points of resemblance to some of the above-mentioned meteorites.

This dunite is a crystalline granular aggregate of olivine and chrome iron, which passes by alteration into serpentine: we have also picrite, half of which is olivine, associated with hornblende, diallage, and magnetite. Lherzolite is another of these peridote rocks, consisting of olivine and enstatite, with other accessory minerals. Olivine is the dominant constituent of such rocks, and as a class they possess the highest specific gravity and least oxygen of any known.

Some of the basalts, notably those of Antrim, in Ireland, contain metallic iron in microscopical particles, and Prof. Nordenskiold discovered in 1870, on the shores of Disco, on the coast of Greenland, at Ovifak, fifteen blocks of nickel iron within an area of half an acre, the two largest being 20 and 8 tons weight respectively; while further observations in the same locality showed that a basalt dike, at no great distance from the supposed meteorites, contained lenticular disk-shaped blocks of precisely similar iron, and crystals of labradorite and arigite associated with viridite, round which minute particles of iron were moulded.

These facts led Professors Judd, Daubree and others to decide that the blocks of iron Nordenskiold discovered and took to be meteorites were of terrestrial origin, as the basalt was certainly not derived from the clouds.

The Ovifak iron contains 0·5 to 6·5 of nickel, and a nickel iron awaruite, lately discovered in New Zealand, presumed also to be of terrestrial origin, is said to contain 68 per cent. Ni, 31 per cent. Fe and 0·7 per cent. cobalt.

In the Urals platinum is found alloyed with nickel iron in association with olivine. Taking the mean density of awaruite as approximately 7·1, and that of rhyolite as 2·6; the terrestrial basic and ultra-basic rocks, which include basalt, gabbro, lherzolite, trachite and dolerite, are found to closely correspond in density with the extra-terrestrial meteorites. Those of solid nickel iron have a specific gravity of 7·1 and graduate down to stony asiderites, which possess a density of 2·7.

Meteorites.

	Sp. gr.
Nickel iron solid	7·1
" considerable	6·8
" medium proportion	3·5
" small quantity	3·1
Stony	2·7

Terrestrial metals and rocks.

	Sp. gr.
Awaruite	7·1 approx.
Nickel iron in Ovifak basalt	6·8 "
Basalt, gabbro, lherzolite	3·0 to 3·5
Trachyte and dolerite	2·7 to 2·9
Rhyolite petro-silex	2·6

The conclusion to be drawn appears to be that the genesis of nickel deposits may, in most instances, be traced to the ultra-basic rocks, and their derivatives, serpentines and magnesian silicates. The great nickel deposits of the world are found in rocks in which olivine is the predominant mineral, while we have seen that olivine and the magnesian silicates are found not only in the ultra-basic rocks of the earth, but also in meteorites. While these facts alone do not prove that the nickel was derived from the olivine, it is well to note the conditions under which the olivine was formed and to see how far it is nickeliferous. Assuming a semi-metallic nucleus for the earth, and that in this nucleus iron and nickel are the predominant metals, as they are in meteorites, and allowing that the ultra-basic rocks came from the greatest depths in the earth's interior, under such circumstances it would not be remarkable for silicates, crystallizing out of the magma, to contain such metals.

From the microscopic study of the igneous rocks, much light has been thrown on the order of crystallization of their component minerals, which has pretty definitely been proved to be fairly uniform. Thus the first minerals to form appear to be magnetite and ilmenite, sometimes chromite and picotite. Next come silicates, which occur in minute quantities, such as zircon and titanite; pyrite and pyrrhotine usually follow; and next the metallic oxides and sulphides, and the heavy dark colored basic silicates, olivine, augite and hornblende.

Olivine is the first of the rock-forming silicates to crystallize out of the basic magna. According to "Rutley," p. 117, olivine sometimes contains traces of titanic, phosphoric and chromic acids, and the protoxides of nickel and cobalt.

Sandberger's experiments with rock silicates almost invariably show traces of Ni, Co and Cu, from olivine and augite: whether the nickel occurs, as he supposes, in chemical combination, or, as A. W. Stelzner thinks, mechanically admixed, is practically immaterial to the question under discussion; it is sufficient to know that olivine contains the metal in quantity enough to form, when dissolved and reprecipitated, rich and extensive deposits. We have seen, indeed, that the olivine in the Oregon rock gave 0·25 per cent. Ni, while the serpentine from Dillenberg showed 0·66 per cent., and much of the serpentine in New Caledonia runs over 1 per cent.

A review of the foregoing facts certainly points to the conclusion that the nickel, at least of the serpentinous deposits, has been derived from the basic magnesian silicates of the original rock masses. As regards the nickeliferous pyrrhotite deposits, they may possibly have a different origin, as suggested by Vogt.

It has been proved that workable deposits of titaniferous iron have been probably formed in certain basic eruptives in Norway and Sweden, by a process of differentiation or segregation of the iron ore to the center of the eruptive mass; and Vogt has suggested, and endeavored to apply, the same theory, to account for the formation of the nickel sulphide deposits in the norites of Norway and Sweden and the Huronian deposits of Canada. As against this theory, it is remarked that the pyrrhotite deposits referred to occur along the contact planes of the gneiss and schists; and, therefore, if they were formed by segregation from a molten magma, this process has taken place from the center toward the outside, or in reverse order to that which characterizes the iron ore and the supposed structure of the interior of our globe.

Though there may be grounds for further investigation in this direction, these ore bodies would seem more probably to have been deposited from circulating mineral waters. Some geologists explain the presence of deposits of mineral by supposing them to have been formed by the agency of circulating solutions bringing them to the surface from unknown depths, disregarding the fact that fissures have never yet been proved to have indefinite extension, nor can water circulate below certain limits.

Before, therefore, adopting an ascension theory for the formation of nickel deposits in basic eruptives, it is well to recollect that these rocks came from greater depths within the earth than circulating water is likely to have penetrated; much deeper in all probability than any vein fissure could have extended to.

It is more rational, it seems to me, to suppose that the metals were brought within reach of surface agencies, and it is probably owing to the subsequent leaching of these basic eruptives that our principal deposits of nickel were placed at the disposal of the miner's pick. The practical lesson to be gathered from this is,

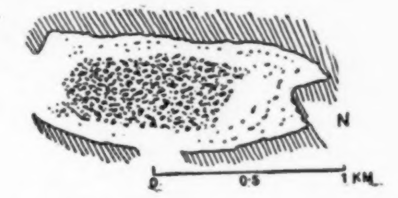


FIG. 3.—SEGREGATION OF IRON ORE.

I think, that the "prospector," looking for new deposits of this class, will best turn his attention to a field where rocks of this character are met with.

The progress of science day by day makes the art of mining less speculative and more business-like, and it should be, I think, the function of the engineer to apply science to this legitimate commercial end; to raise it, in fact, into the position of an "industry," which has materially assisted in building up the prosperity of all new countries; which has done so for America already, and which will do so for our British colonies in the future, with marked advantage to us.

Mining supports tens of thousands of our population, opens outlets for remunerative enterprise and emigration, and exercises a civilizing influence, which is world wide, and, I think, the surest means to foster it is to point out its risks, as well as its advantages; to encourage the employment of necessary capital in profitable fields; and, equally, to discourage wasting valuable money on enterprises which do not possess the elementary conditions for achieving success. There are, in fact, three classes of people, I believe, who engage in mining: those who get most "metal" out of the pockets of the public, those who are content to mine in "pockets of ore," and those whose endeavor is to successfully develop valuable mineral deposits on what I would term a profitable commercial basis, with the aid of scientific knowledge applied practically.

The contracts for the metal in America closed early in 1892 were made at prices ranging from 55 to 60 cents per pound, these quotations being for metal of 98 to 99 per cent. fine. Later on very good nickel of the same fineness has been offered at 52 to 54 cents, and at the close of 1892 could be bought for 50 cents. The dry process has greatly tended to cheapen the cost of producing nickel, but this, it must be recollected, is offset when there is a demand for metal of extreme purity, which can only, as yet, be obtained by wet treatment. This feature of the nickel confers a great advantage on the New Caledonian ores; to illustrate it, it may be stated that the leading nickel refiners in the United States asked 70 cents per pound for metal of first-class quality, while the price asked for the regular 98 per cent. grade was 56 cents prepared from the same ore.

In presenting you with these notes, I have to acknowledge my indebtedness to the papers of Mr. W. S. Austin and Mr. Ph. Argall, before alluded to, and I regret that the limits of this paper will not permit me to enter into the ore dressing and metallurgical treatment of nickel. Both are subjects of special interest to mining men like myself, owing to the important place nickel may take in the future in many branches of the arts and engineering construction, provided only it can be produced at a more moderate cost than it can be placed on the market for at the present time; a necessary condition, which, in time, will certainly be attained.

I have to acknowledge my indebtedness to Prof. Judd and Mr. Gregory for a series of specimens they have most kindly lent me to illustrate the rocks and ores I have referred to.

Mr. Charleton, in reply to questions, said the production of nickel ores in New Caledonia was certainly on the increase. In 1890 the production was 22,690 tons and in 1891 35,000 tons. The lowest price at which it had yet been sold in America was 48 or 50 cents, and though the Americans expected it to come down to 36 cents, he thought that was rather a distant prospect at present. That was for ordinary 98 per cent. quality; that made by the wet process involved a higher cost. With regard to the North Carolina mines, the deposits occupying fissures, the strike of which was normal to the plane of division of the chrysolite mass, were considered likely to be most productive. He had heard recently something about the Mond process, which, he believed, was being tried on a working scale in the States, but he had not yet been able to obtain full details. With regard to the deposits of iron ore containing nickel, though the presence of the latter metal was a decided advantage in certain classes of steel, he did not think it could be considered so in iron; it made it "red short," especially with a low tenor of carbon, and therefore was extremely deleterious above a very small percentage. The chairman's explanation of the origin of the name was probably correct. His intention was certainly not to suggest that the prospector should confine his attention to any particular class of deposits; he knew the unexpected often happened, and the case mentioned in North Wales, where the deposit of nickel occurred in limestone, was somewhat parallel to one he had mentioned in the paper: the occurrence of millirite in calcite in Iowa, mentioned by him. Of course, almost any statement with regard to mining must be made in more or less general terms; one could not dogmatize, and say that such a thing would always happen; the exception was always sure to turn up, and prove the rule. All he wished to point out was that ultra-basic rocks, containing olivine, offered a likely field in which the prospector should look about him with the idea of discovering nickel, though such rocks might cover a large area and yield none.

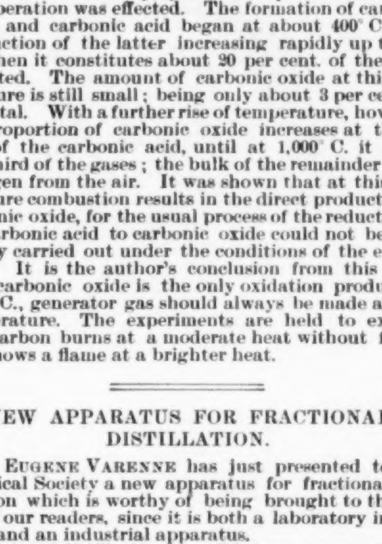
THE BEST TEMPERATURE FOR GAS PRODUCERS.

HERR R. ERNST has been experimenting with a view to ascertaining the conditions under which producer gas is made from air and carbon. Coke was coarsely powdered, freed from dust by sifting, and roasted at a very high temperature in a Hessian crucible to remove hydrocarbons. It was then burnt in a current of air passing through a porcelain tube heated in an ordinary combustion furnace; and the resultant gases were arrested and analyzed. The temperature of the interior of the tube was checked during the experiments by means of a Le Chatelier pyrometer. The length of the layer of coke, the rate of passage of the air, and the temperature, were independently varied in the experiments. As a general result, it was found that the composition of the gaseous products of combustion depended almost entirely upon the temperature at which the operation was effected. The formation of carbonic oxide and carbonic acid began at about 400° C.; the production of the latter increasing rapidly up to 700° C., when it constitutes about 20 per cent. of the gases collected. The amount of carbonic oxide at this temperature is still small; being only about 3 per cent. of the total. With a further rise of temperature, however, the proportion of carbonic oxide increases at the expese of the carbonic acid, until at 1,000° C. it forms one-third of the gases; the bulk of the remainder being nitrogen from the air. It was shown that at this temperature combustion results in the direct production of carbonic oxide, for the usual process of the reduction of the carbonic acid to carbonic oxide could not be completely carried out under the conditions of the experiment. It is the author's conclusion from this that, since carbonic oxide is the only oxidation product at 1,000° C., generator gas should always be made at this temperature. The experiments are held to explain why carbon burns at a moderate heat without flame, but shows a flame at a brighter heat.

NEW APPARATUS FOR FRACTIONAL DISTILLATION.

MR. EUGENE VARENNE has just presented to the Chemical Society a new apparatus for fractional distillation which is worthy of being brought to the notice of our readers, since it is both a laboratory instrument and an industrial apparatus.

Fractional distillation, as well known, was especially applied in laboratories of organic chemistry by the lamented chemist Wurtz. He was the first to devise an apparatus which is still employed under the name of the Wurtz tube. Two of his pupils, Messrs. Le Bel and Henninger, greatly improved the Wurtz tube and



APPARATUS FOR FRACTIONAL DISTILLATION.

constructed the ordinary apparatus that is now widely distributed among laboratories.

Mr. Varenne, who likewise was a pupil of Wurtz, has just effected a new progress in fractional distillation through the contrivance of the apparatus represented in the accompanying figures.

For chemical laboratories, the apparatus may be made of glass, and will permit of easily effecting the fractional distillation of liquids at very approximate points of ebullition. For the industries, it is constructed of copper or iron.

It is well adapted for the delicate distillation of benzine or toluene, and it is applicable to all distillations, whatever be the boiling points of the liquids. It suf-

fices to vary the number of the bulbs according as the liquids boil at more or less elevated temperatures.

It is principally in the rectification of alcohols that this apparatus gives good results.

The following, according to the communication made by the inventor to the Chemical Society of Paris, is a comparative table of the rendering of the different apparatus:

Savalle apparatus	1·580
Le Bel-Henninger apparatus	1·560
Claudan-Morin apparatus	1·530
E. Varenne apparatus	1·083
Theoretical coefficient	1·025

The new apparatus is, therefore, the one that most nearly approaches the theoretical coefficient.—*Le Genie Civil.*

OPERATION FOR CATARACT.

The operation for cataract was recently performed upon Mr. Gladstone at the residence of Lord Rendel, in London, by Drs. Nettleship and Habershon. It was completely successful, and the aged statesman, who was cheerful during the performance of the work, has since been receiving the congratulations of his friends, among whom was the American ambassador. This operation which Mr. Gladstone has just undergone represents, says the N. Y. *World*, one of the highest triumphs of surgery. It requires a precision and deli-

GLADSTONE WEARING HIS EYE SHIELD.

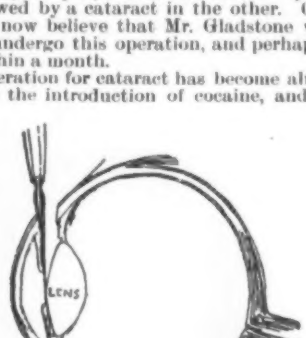
cacy of touch which no other operation calls for, and it necessitates the employment of instruments so fine that a hair's breadth differentiates one from the other.

Of all the human organs, the eye in its structure and functions is the most wonderful as well as the most delicate. Within the compass of less than an inch this organ embodies tissues which enable the mind to see and a lens which adjusts itself to every focus by an instinctive and unconscious process. The only result of the operation for cataract which Mr. Gladstone has just undergone, and which is performed every week in this city, is the loss of this little lens in the eye. That loss will now be supplied by eyeglasses of varying strength, but they are clumsy and awkward compared with the marvelously perfect lens which nature puts into the eye of every man.

Although the lens is embedded deep in the eye, it has nothing whatever to do with the delicate adjustment of sensitive nerves less than an inch away that enable a man to see. The faculties of sight are not at all impaired or in any way affected by the operation for cataract, although the latter involves very deep cutting into the eye and the removal of one of the parts which go to make it a perfect seeing organ.

The operation upon Mr. Gladstone was performed at 9 A. M., and did not take longer than fifteen minutes. There have been many occasions when the operation for cataract has been performed twice upon the same person in less than an hour, when both eyes were affected. In very old people a cataract in one eye is generally followed by a cataract in the other. Oculists in this city now believe that Mr. Gladstone will again have to undergo this operation, and perhaps he may do so within a month.

The operation for cataract has become almost painless since the introduction of cocaine, and no anæs-



CUTTING OUT THE LENS.

thetic was used in the case of Mr. Gladstone. The greatest inconvenience of the patient, however, comes from the enforced incarceration in a dark room for several weeks following the operation. This is to enable the tissues of the eye to heal before any work is thrown upon that organ. The light is gradually let into the darkened room, and the patient, at the end of about three weeks, is released fully cured.

It would be almost impossible for any one but an experienced oculist to tell that the eye had been operated upon. It is apparently natural and unimpaired in every respect, being full and round, of good color, and exactly like its fellow. Similarly, it is very difficult to detect the presence of a cataract in the eye for any non-professional. Many people think that they can tell when a man has a cataract, and that they can pick out the victims of this disease when walking along the streets. Oculists know that this is a fallacy, and what is regarded as a cataract is not that at all, but some other affection of the eye. A curious thing about this disease is that it is not confined to human beings, and that cataracts are frequently found in the eyes of animals.

Another curious fact about the cataract is that no one knows what causes it. The men of science have not failed to advance theories and speculations as to the cause of the disease, but there is no unanimity of opinion among them on this subject. Attempts have also been made to cure the cataract without resort to the knife, but these are regarded as unsuccessful, and the surgical and scientific world agrees that

SURGICAL INSTRUMENTS USED FOR REMOVING CATARACT.

A, eye speculum; B, capsule forceps; C, lid retractor; D, instrument for exhausting soft cataract; E, trachoma forceps; F, ophthalmostate; G, knife; H, cataract needle; I, angular shank kertome; J, cystotome; K, double instrument.

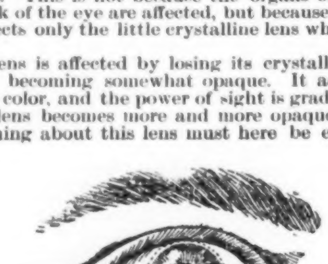
an operation—which is the last resort of science—is in every case necessary.

The idea of operating surgically upon the human eye is one that is appalling when first presented to the mind. He was a bold man who ate the first oyster, but he was bolder yet who made the first operation for cataract. It is believed that the ancients were familiar with the operation. There are passages in Galen and Pliny which are thought to refer to the removal of cataract. These, however, could not have been highly successful. The practice fell into disuse among physicians and surgeons until the middle of the eighteenth century. Even then it was attended with great risk and difficulty, and the percentage of failure was very high.

Now, however, while the operation for cataract requires the utmost skill, the chances of losing the eye are only three out of one hundred. Statistics are accurately kept of the operations for cataract, and every case of failure and success is noted.

There are only two cuts of the knife made in the operation, although a multitude of beautiful and delicate instruments are manufactured for the purpose. One of these cuts almost slices off the front of the eye, but it is a singular thing that, although it severs the delicate covering and goes deep into the interior of the organ, it heals up perfectly and leaves almost no mark. A cataract grows on the inside of the eye. It is not on the outside of the eye, as is generally supposed. The sufferer becomes conscious of its existence generally by a gradual diminution of the power of sight. This is not because the organs of sight in the back of the eye are affected, but because the cataract affects only the little crystalline lens which intervenes.

This lens is affected by losing its crystalline quality and becoming somewhat opaque. It acquires a whitish color, and the power of sight is gradually lost as the lens becomes more and more opaque. A singular thing about this lens must here be explained.



THE UPWARD CUT.

While it is really a little sac of liquid, shaped like the ordinary convex lens, it yet contains in its center an actual lens of clear gristle that is hard and strong. This is surrounded by clear liquid. The shape of the entire lens is constantly changing in daily life. When you look at a mountain ten miles off the lens in your eye is of one shape, but when you look at the ground at your feet it instantly changes its shape, so as to bring the subject looked at into focus.

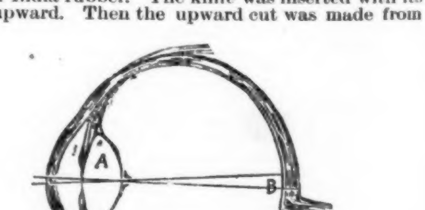
As the whole of the lens is affected in a cataract, its entire removal from the eye is necessary. If it were not for the little hard lens in its center the entire lens might be taken out through a small opening made with an instrument, being run out like so much water. But the little hard lens is more than a quarter of an inch across its face and an eighth to a sixteenth of an inch in thickness. It can only be removed through a slit cut down to the center. This is the first cut which is made.

In performing the operation it is necessary that the eye should be kept immovable. The patient could not do this himself. The oculist first inserts a speculum, which keeps the eyelids far apart and the eye wide open. The patient might, however, move his eye with the speculum in place. This is prevented by the use of a forceps, which grasps the skin of the eye below the eyeball and holds it firmly. This is generally held by an assistant of the operator. Another assistant holds a large magnifying glass which concentrates the light on the eye and illumines its interior.

The patient always undergoes the operation after having had a rest. That is the reason the operation on Mr. Gladstone was performed early in the morning. This is the time of day invariably selected by oculists, because the patient is fresh from his bed and thoroughly rested. Oculists also prefer to perform the operation by artificial light, which seems to be softer and more congenial to the eye than the light of day.

A *World* reporter, who called upon an eminent oculist in this city recently, enjoyed the rare opportunity of seeing the operation for cataract performed. In this instance a human eye, taken from a bottle of alcohol, was used in illustration, being placed in the mask or false face which oculists use for this purpose. The knife with which the first cut was made had a blade that was about an inch in length, sharpened on one edge, with a very sharp point. As soon as the oculist began to work upon the eye it became apparent that that organ in the body is by no means as delicate as is commonly supposed. This was not because of the alcohol in which the specimen had been placed. "The eye is really well protected," said the doctor. "In the operation for cataract considerable muscular pressure is required. People generally think the eye is a bag of liquid contained in a thin film. As a matter of fact, it is protected by a covering that is almost as tough as leather."

It was apparent when the first cut was made that the operator requires strong hand and fingers. The knife was run into the eye horizontally from the outside. After the first puncture it was pressed steadily through the center of the eye toward the nose, until it came out upon the other side. The coverings of the eye which were being cut seemed to be of the consistency of India rubber. The knife was inserted with its edge upward. Then the upward cut was made from



CROSS SECTION OF EYE.

A, lens, which is removed. D, retina.

this position, the knife being worked backward and forward until it came out at the top of the eye. This left a sort of flap.

The patient always reclines on his back, and the flap remains in a natural position until the next instrument is inserted. This is really a long needle with a slight elbow, on the end of which is a minute point projecting inward with a knife edge on its upper surface. The little knife which this instrument carries on its point is so small as almost to be invisible to the naked eye. Its purpose is to cut the sac containing the lens, which has thus far escaped the knife. This instrument is inserted through the cut which has just

been made from the top and at an angle projecting outward. When its end has passed the center of the eye the operator changes the angle and gives the instrument a slight turn between his fingers, so as to bring the little pointed knife inward. He now presses the latter into the lower part of the sac containing the lens and draws it sharply upward with his fingers.

The result of this is to sever the envelope of the lens, and the liquid immediately begins to run out. A pressure of the finger on the outside of the eyeball is now all that is required to bring the little hard lens to the surface. It slips out through the opening made in the transparent filmy covering of the lens, and pressure on the bottom of the eyeball then makes it come out at the top. That is all the surgery that constitutes the operation for cataract, divested of the multitude of scientific terms employed in the profession.

A natural question at this point is, "What takes the place of the lens? Doesn't it leave a hole in the eye?" The cavity in the eye occupied by the lens fills up with vitreous humor within less than three minutes after the removal of the lens. This substance is supplied to the eye in abundance by nature, and is being constantly replenished. The place in the eye that was occupied by the lens fills with this transparent substance, and the whole organ retains its original shape and form. The transparent film which had formerly been the envelope of the lens folds back out of the way of its own accord, leaving the field clear and unobstructed from the retina at the extreme back of the eye through the iris, the anterior chamber and the cornea. Thus the intervening obstruction formed by the affected lens, and called the cataract, has been removed and the eye can see with its former vigor and clearness.

GRANULAR EFFERVESCENT PREPARATIONS.*

By AUGUSTUS BRADLEY.

THIS form of medication is a most pleasing one for the exhibition of many nauseous and disagreeable medicines and those remedies where the assistance of the sedative action of carbonic acid is desired.

Not many years ago the effervescent draught was considered indispensable, but at present it has comparatively fallen into an unmerited oblivion.

It is, however, again making its appearance in such localities where it is extensively advertised.

The efficacy of these preparations, as a class, depends principally upon the amount of available carbonic acid gas contained therein. The worthless (non-effervescent) stock upon our shelves, in main, prompted me to devise a scheme whereby they could be supplied by the pharmacist fresh on a short notice.

MODE OF PREPARING.

I propose in this paper to relate a few experiments, with results, also giving methods and formulas, with an apparatus of my own get up, whereby the retail pharmacist can prepare his own granular effervescent preparations, and not be dependent upon the wholesale manufacturer as heretofore. These preparations are made by causing a mixture of powdered ingredients, consisting of sodium bicarbonate, tartaric or citric acids, sometimes both, and the medicament to become sufficiently moistened, as when in such pasty condition, rubbed through a coarse sieve and dried, granules are produced.

Each article should be separately powdered and dried before mixing, the citric acid to be added last and rubbed in quickly.

The drying apparatus should be previously heated for the reception of the moist granules. The proper pasty consistency of the mixture is only ascertained through practice, some mixtures requiring more of the moistening agent than others.

SELECTION OF A MOISTENING AGENT.

The selection of a cheap moistening agent seems to me to be an item of great importance, especially when large quantities are to be made.

Samples are prepared with ether, amylic alcohol, chloroform, live steam, sirup, carbon disulphide, etc., but with each too great a loss of carbon dioxide resulted during manipulation to encourage the use of any.

Water or moisture being the prime cause of this loss, I concluded that if a liquid containing no water at all be used, granules could be made without any loss of gas.

I was aware that absolute alcohol contained practically no water, but also that, if it answered from this standpoint, its expensiveness would discourage its use. However, a small quantity of a mixture was tried, but owing to the hygroscopic properties of this alcohol, the experiment proved a failure. In a few minutes after the granules had been removed to be dried, decomposition took place, resulting in an adherence and puffing up of the granules, showing too great a loss of gas.

Purified benzin was next tried, but owing to the disagreeable taste, odor, and too easily crushed condition of the dried product, it was abandoned.

Benzin, with different percentages of absolute alcohol, resulted likewise.

After numerous experiments I found 95 per cent. (by volume) ethylic alcohol, as recommended by the National Formulary, to be the best agent for general use.

SIEVES.

I use four copper wire sieves, Nos. 6, 20, 40 and 60, No. 6 to pass the pasty mass through the glass shelf, No. 20 to separate the dried granules from the dust (some manufacturers, to prevent any loss, do not separate it). Nos. 40 and 60 are used for thoroughly mixing the different ingredients.

I like the copper wire sieves the best, owing to their less liability of being attacked by corrosive agents.

The temperature of the drying apparatus, with but a few exceptions, should always be constant, taking care not to allow it to go above 158 degrees F., for fear of converting the sodium bicarbonate back into the carbonate, through the loss of carbon dioxide, and also the formation of caramel in those preparations containing sugar with tartaric acid.

LOSS IN WEIGHT.

The loss in weight encountered in drying the following articles, as found in commerce, are:

Citric acid, 8 to 10 per cent.
Sodium bicarbonate, 2 to 3 per cent.
Tartaric acid, 1-500 per cent.

The use of tartaric acid alone, as recommended by the National Formulary, leaves the granules too soft. An addition of citric acid will give them firmness, and render their taste more acceptable to the majority of people.

There is no class of preparations that require such special care as these. The absence of moisture is absolutely essential; therefore the bottles should be thoroughly dried and hermetically sealed immediately after being filled. Those composed of iron, pepsin, and their compounds should be stored in amber or blue glass bottles.

I will submit a few formulas, which I have compiled and am using, most of which in course of preparation require some special precautions, which will, however, present themselves to the operator upon his first attempt:

1. GRANULAR EFFERVESCENT CAFFEINE CITRATE.

Caffeine citrate	20 grains
Sodium bicarbonate	600 grains
Citric acid	300 grains
Tartaric acid	240 grains
Powdered sugar	600 grains

2. GRANULAR EFFERVESCENT CAFFEINE CITRATE AND PHENACETIN.

Caffeine citrate	20 grains
Phenacetin	100 grains
Sodium bicarbonate	600 grains
Citric acid	300 grains
Tartaric acid	240 grains
Powdered sugar	620 grains

3. GRANULAR EFFERVESCENT POTASSIUM BROMIDE.

Potassium bromide	½ troy oz.
Sodium bicarbonate	3¾ troy oz.
Tartaric acid	1¼ troy oz.
Citric acid	2 troy oz.

4. GRANULAR EFFERVESCENT CAFFEINE CITRATE AND POTASSIUM BROMIDE.

Caffeine citrate	50 grains
Potassium bromide	½ troy oz.
Sodium bicarbonate	3¾ troy oz.
Tartaric acid	1¼ troy oz.
Citric acid	2 troy oz.

5. GRANULAR EFFERVESCENT MAGNESIUM SULPHATE.

Dried magnesium sulphate	400 grains
Tartaric acid	300 grains
Citric acid	240 grains
Powdered sugar	460 grains
Sodium bicarbonate	600 grains

This is practically identical with the granular effervescent magnesium citrate on the market.

6. GRANULAR EFFERVESCENT VICHY SALT.

Potassium bicarbonate	45 grains
Sodium bicarbonate	5 troy oz.
Magnesium sulphate	45 grains
Sodium carbonate	5 troy oz.
Tartaric acid	1½ troy oz.
Citric acid	2 troy oz.

7. GRANULAR EFFERVESCENT PEPSIN.

Pure powdered pepsin	50 grains
Citric acid	1¾ troy oz.
Tartaric acid	1½ troy oz.
Powdered sugar	½ troy oz.
Sodium bicarbonate	3¾ troy oz.

8. GRANULAR EFFERVESCENT PEPSIN AND BISMUTH.

Pure powdered pepsin	50 grains
Bismuth and ammonium citrate	50 grains
Citric acid	1¾ troy oz.
Tartaric acid	1½ troy oz.
Powdered sugar	½ troy oz.
Sodium bicarbonate	3¾ troy oz.

* From a paper read before the North Carolina Pharmaceutical Association.—*American Druggist.*

TESTS OF TRANSPARENCY.

ACCORDING to a paper published in the *Journal fur Praktische Chemie*, the author has made some experiments upon the determination of the transparency of different media by means of Crookes' radiometer. With this object, he first investigated a method of ascertaining accurately the rate of rotation of the vanes of the radiometer. The instrument was inclosed for this purpose in a metal case, blackened on the inside, and open in the direction of the radiant rays. This case was provided with a side tube, through which the observer could see the vanes rotating. When a rotating vane came into a certain position with relation to the source of light and the eye of the observer, a flash of light was seen. By means of a chromascope, the instant at which this flash occurred was noted. A convenient number of transits of the vanes were observed and counted: and the time occupied was again determined by the aid of the chromascope. The method is susceptible of a considerable degree of accuracy; and it was first employed in experimentally testing the action of the radiometer when the instrument was first at a distance of 20 centimeters from the source of light, and secondly at twice the distance. In three successive experiments, the ratio of the numbers representing the revolutions of the vanes was found to be 3·95, 3·99, and 4, which is exceedingly near the theoretical value as given by the law of radiation. In endeavoring to measure the transparency or the diaphaneity of bodies, the author used a couple of radiometers exposed to the same source of light, and adjusted to revolve at the same rate of speed. The plate or solution to be examined was then introduced in front of one of them; and by readjusting the distances the rates of revolution could again be equalized. The diaphaneity of water being taken as unity, it was found in this way that saturated aqueous solutions exhibit only slight differences in diaphaneity. The addition of sodium chloride increased it by 3·75 per cent., while oxalic acid lowered it to 98·79 per cent.; but nothing else made so much difference. The diaphaneity of carbon bisulphide, 141·70, exceeds that of glass, which is 140·77; and it is noted that carbon tetrachloride, which has the index 145·77, is more diaphanous than air, which stands at 142·26 in the same scale.

TABLE OF ATOMIC WEIGHTS, REVISED TO JANUARY 1, 1894.*

By F. W. CLARKE.

Name.	Atomic weight.
Aluminum	27·0
Antimony	120·0
Arsenic	75·0
Barium	137·43
Bismuth	208·9
Boron	11·0
Bromine	79·95
Cadmium	112·0
Cæsium	132·9
Calcium	40·0
Carbon	12·0
Cerium	140·2
Chlorine	35·45
Chromium	52·1
Cobalt	59·0
Columbium	94·0
Copper	63·6
Erbium	166·3
Fluorine	19·0
Gadolinium	156·1
Gallium	69·0
Germanium	72·3
Glucinum	9·0
Gold	197·3
Hydrogen	1·008
Indium	113·7
Iodine	126·85
Iridium	193·1
Iron	56·0
Lanthanum	138·2
Lead	206·95
Lithium	7·02
Magnesium	24·3
Manganese	55·0
Mercury	200·0
Molybdenum	96·0
Neodymium	140·5
Nickel	58·7
Nitrogen	14·03
Osmium	190·8
Oxygen	16·0
Palladium	106·6
Phosphorus	31·0
Platinum	195·0
Potassium	39·11
Praseodymium	143·5
Rhodium	103·0
Rubidium	85·5
Ruthenium	101·6
Samarium	150·0
Scandium	44·0
Selenium	79·0
Silicon	28·4
Silver	107·92
Sodium	23·05
Strontium	87·6
Sulphur	32·06
Tantalum	182·6
Tellurium	125·0
Terbium	160·0
Thallium	204·18
Thorium	232·6
Thulium	170·7
Tin	119·0
Titanium	48·0
Tungsten	184·0
Uranium	239·6
Vanadium	51·4
Ytterbium	173·0
Yttrium	89·1
Zinc	65·3
Zirconium	90·6

Oxygen = 16 is taken as the base of the system, but for provisional reasons only. Before long, with improved determinations, it may be practicable to return to the more philosophical H = 1, when the entire system can be transformed once for all into something like permanent shape. A premature transformation of this kind, however, would only work confusion, without corresponding benefit.

SODIUM PEROXIDE.

FURTHER interesting properties of sodium oxide are described in the current *Berichte* by Prof. Poleck, of Breslau. It is shown that sodium peroxide rapidly reduces salts of gold, silver and mercury, with separation of the metal and evolution of oxygen gas. Platinum, however, is not precipitated from chloroplatinic acid or chloroplatinates until they are decomposed with silver salt, when reduction both of the resulting platinum chloride and of the silver chloride occurs, both metals being precipitated. Ferric hydroxide is precipitated, as might be expected, from both ferrous and ferric salts; from manganous salts manganese dioxide is precipitated, presumably hydrated; and from salts of cobalt, the higher cobaltic oxide. Permanganates are reduced to manganese dioxide, but chromic oxide is oxidized to chromic acid. The separation and quantitative estimation of iron and chromium or manganese and chromium are easily achieved by utilizing these reactions, for iron is precipitated as ferric hydroxide and manganese as peroxide, while chromium remains in solution as chromate of sodium. Sodium peroxide also produces the highly oxidized sodium peruranate, $Na_4U_2O_8+8H_2O$, directly from salts of uranium, and it may readily be isolated by addition of alcohol, which precipitates it. It is also interesting that iodine is oxidized on warming directly to the difficultly soluble acid sodium periodate, and upon decomposition of this salt with silver nitrate the normal silver periodate is at once produced, and free periodic acid HIO_4+2H_2O may be readily obtained from it in large crystals by decomposition with bromide and sub-

* From the report of the commitee on determinations of atomic weight published during 1893.—*Journal of the American Chemical Society.*

THE VISIT OF MILTON TO GALILEO AT THE VILLA D'ARCETRI, NEAR FLORENCE, IN 1638.

From the Graphic, London.

sequent evaporation *in vacuo*. Potassium ferricyanide behaves toward sodium peroxide in a similar manner to its action with hydrogen peroxide, reducing it energetically to ferrocyanide, and the volumetric process of Kassner can be readily carried out by use of it. Sodium peroxide reacts with lead oxide in presence of water to produce a plumbate of sodium of the composition $Na_2PbO_3+4H_2O$. Organic compounds dissolved in alcohol are usually very rapidly oxidized by sodium peroxide, while the alcohol itself is not attacked. Ether, on the contrary, at once ignites when brought in contact with the peroxide.

MILTON'S VISIT TO GALILEO.

IN 1638 Milton, then in his thirtieth year, commenced his famous continental journey. Hurrying through France, which to him presented little interest, he reached Florence, the ultimate object of his journey, early in August of the same year. In the environs of this city was then living Galileo, the great Italian philosopher and astronomer, in the Villa d'Arcetri, where the last years of his life were spent. Galileo was then in his seventy-fourth year and had within a few months become totally blind. His eyesight, however, was the only sense affected by age, and he still found a pleasure in explaining his theories and reciting his poems to travelers who came to pay homage to his learning. After all the persecution which he had undergone, Galileo had then been allowed to return to Tuscany, but under certain conditions and restrictions imposed by the Holy Office, which made him nominally a prisoner. So until his death, in 1641, he lived in the Villa d'Arcetri, and it was here that Milton saw him—old, frail, and blind, through still vigorous in intellect, and keenly enjoying the society of the young men.—*The Graphic, London.*

THE RECENT EGYPTIAN DISCOVERIES.

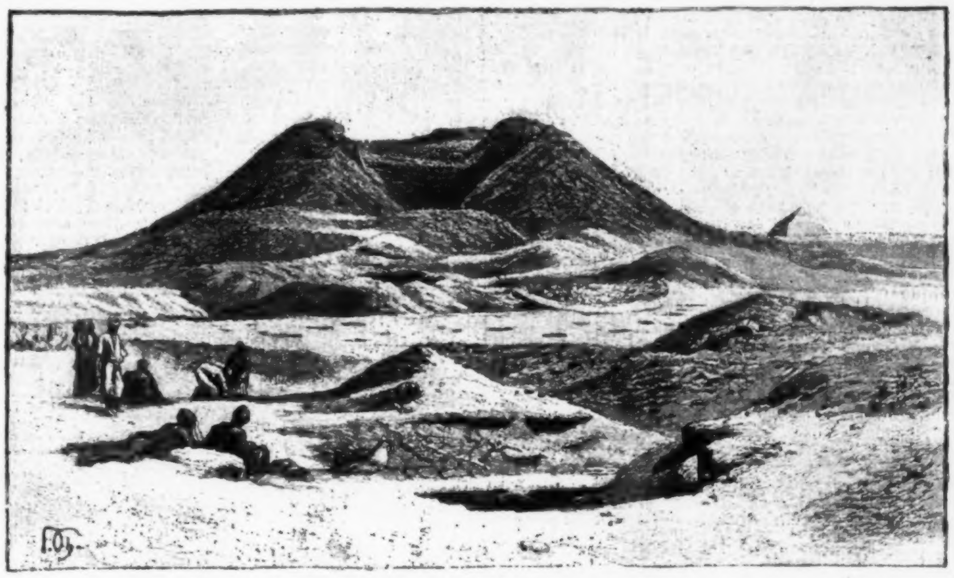
IN our last SUPPLEMENT, 964, page 15410, we gave a number of illustrations of the recently discovered remains of the pyramids of Dahshur, and we now present some additional views pertaining to the same subject. The reader is referred to the above article for descriptions of the present engravings, which are from *L'Illustration.*

The following is from the *London Times.*

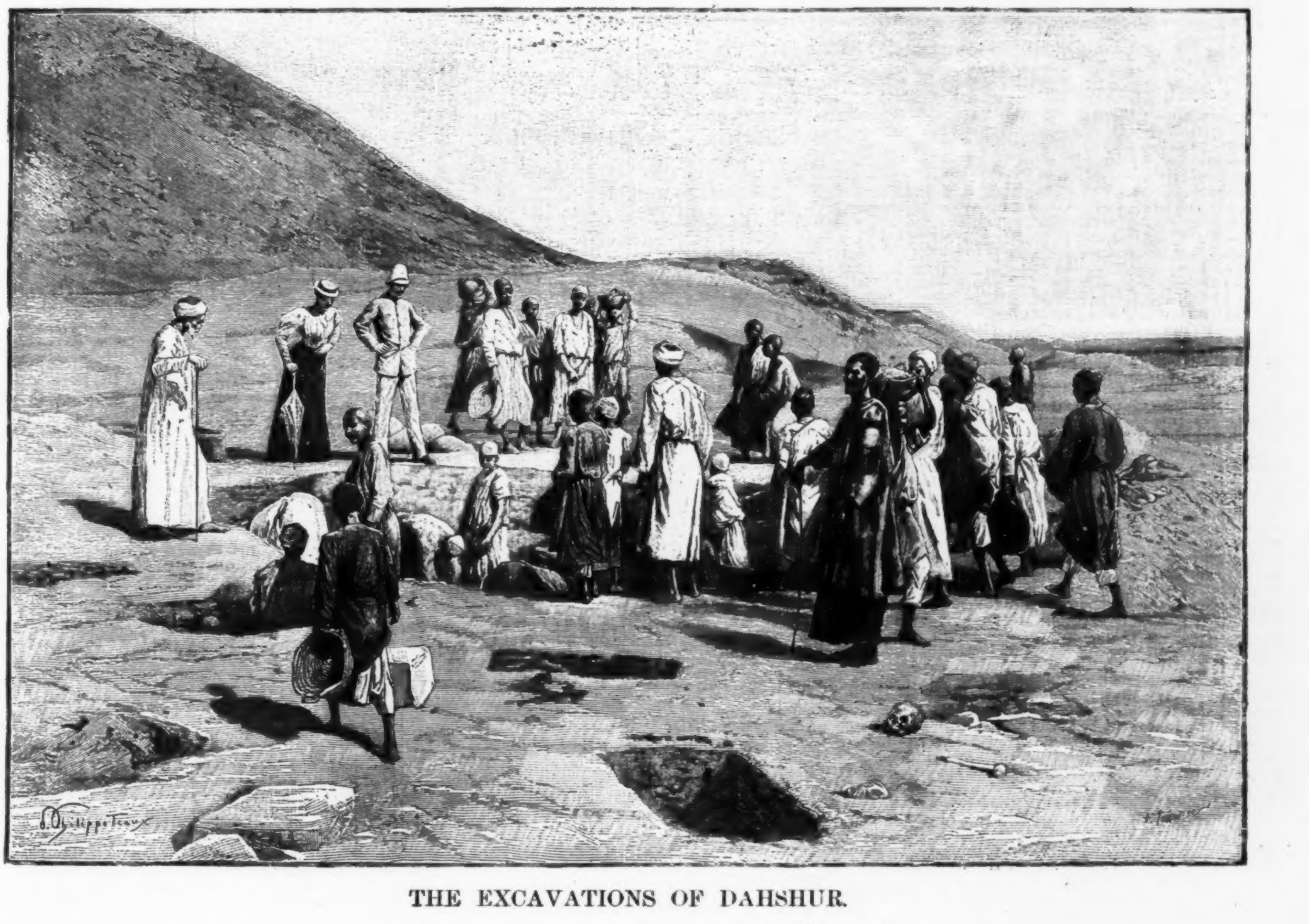
Every season brings more and more spoil of the Egyptians, and it is always the unexpected that we must expect. A private tomb gave up the Kings of Thebes; the vaults of a priestess of Hathor were found filled with mummies of priests of Amen. Priceless scraps of literature have been recovered from cheap *papier-mache* coffins, and farm accounts have been known to bear a lost poet on their reverse. The latest surprise is that, in a Memphite tomb, rifled ages ago, hard by a pyramid, supposed to be of the 6th Dynasty, has been discovered a royal treasure of the twelfth.

The pyramids of Dahshur rise on the left as one rides to the Memphite necropolis at Sakhara, the nearer one being a formless mass of brickwork, almost cut in half by treasure seekers, and buried deep in drift. No royal chamber has ever been found in it, and M. De Morgan, the present Director-General of the Service of Antiquities, conceived the idea that it might be only an enormous *mastaba*, built above the royal tomb. He began, therefore, in February last to dig about its roots in the hope of hitting the mouth of the shaft by which the burial must have been introduced from outside. The desert all round the pyramid base was found full of tombs, square-bricked shafts descending from ruined *mastabas* to the grave chambers. All had been rifled, and nothing of interest resulted at first but sculptured slabs and *stelæ* from the *mastabas*, and canopic jars and chests. From the foot of one shaft, 30 ft. deep, a winding passage, roughly hacked, was found leading into the bowels of the rock. Groping on, the explorers debouched into a vault, nearly filled by a fine sarcophagus inscribed with the name of Nefert-Heut, a queen. Alas! it was broken and empty, rifled by the same hands that had cut the passage. A door, however, led into another gallery—in this case no thieves' work, but an original part of the tomb. It was straight for a long distance, chambers opening on the left, each with rifled sarcophagi and canopic chests. The farthest group of vaults yielded the name of a princess, Seut-seubetes, but was apparently as empty as all the rest. M. De Morgan, like Schliemann, is not content till he has reached rock, and therefore set his men to pick over the floors, expecting no reward beyond the credit of clearing a fine tomb, structurally interesting, though completely void. In the floor of a passage in the group of chambers belonging to the princess the picks encountered a patch of soft earth. A few inches lower the remains of a silver-encrusted box were disclosed, and piece by piece below its crumbling lid was found the first installment of the treasure of Dahshur. A long necklace of amethyst beads, a second of amethyst, turquoise, carnelian, *lapis lazuli* and gold, a kohl pencil in exquisite gold bead work, a bunch of gold rose petals, three finely cut scarabæi, the gold face of one bearing the royal name of Usertasen III., couchant lions, and other tiny pieces in gold—these were all admirable, but eclipsed by two objects in mosaic work—namely, a pendant or brooch shaped like a lotus and set with *lapis* and carnelian, and a royal pectoral, on which two crowned hawks support the cartouche of Usertasen II. The plumage is in stripes of *lapis* and turquoise, the symbols of the royal name in these and carnelian; the whole is set in gold and worked on the reverse to represent the same scene as the front. Whether for purity of design, exquisite coloring, or absolute finish, it equals any piece of jewelry in existence. It would be a *chef d'œuvre* of the goldsmith's art of to-day; made 4,500 years ago, it is a miracle.

A few yards further along the passage was found a second box hidden like the first. Two large pectorals were in it. On the first, two figures of Amenemhat III. smite the Asiatics; the design is crowded and less pleasing than the pectoral of Usertasen II., though the mosaic of stones and gold is not less finely fashioned. On the third pectoral two hawk-headed apes beneath the cartouche of Usertasen III. trample on prostrate men. Nothing for sheer finish excels this



THE PYRAMID OF DAHSHUR.



THE EXCAVATIONS OF DAHSHUR.

piece in the whole treasure. For the rest we can only give a catalogue of the most beautiful contents of the box. There were large cowrie shells of gold, pestle and mortar in gold and *lapis*, rings with beautifully graven *chatons*, necklaces of amethyst and carnelian, large rose petals—one with a wonderful mosaic center—mirrors with gold handles, gold lion masks, and a second kohl pencil adorned with a pattern of gold beads, soldered on one by one, a marvel of delicate work. There is not a single object in the treasure not remarkable; the whole can be fitly compared only to Schliemann's find in the circle graves at Mycenæ.

Why were these treasure coffers so hidden, and who hid them? Perhaps the legitimate owners, fearing spoliation; perhaps robbers waiting for a favorable moment to carry them away. So cunningly concealed were they that the chief wonder is how they were ever found at all; and M. De Morgan's discovery of them will assuredly rank among the most remarkable successes in the records of explorations. He is digging still for the royal chamber, but up to the present moment the pyramid has preserved its secret inviolate.*

The most considerable excavation carried out during the past season in Egypt has been that of the Exploration Fund in the temple of Queen Hatasu, at Deir el Bahari, near Thebes. If M. De Morgan has revealed a treasure, M. Naville is bringing to light a temple. The unique pile of buildings which the queen erected and adorned to serve as funerary shrine for her father, her husbands, and herself, has been almost entirely buried for ages beneath earth slips and the *débris* of a Coptic convent. Thirty years ago Mariette laid bare a small portion, and enriched the world with the famous wall pictures of the queen's naval expedition to the land of Punt, but the rest was left under mountains of rubbish till last season. Thanks to the Egypt Exploration Fund, the whole of this beautiful monument of the greatest period of the empire is now in process of being exhumed and restored. It is built on three terraces; the upper was cleared almost entirely last season, and among other things a unique high altar was laid bare, and a side of a magnificent ebony shrine of Thothmes II. discovered. The latter is now mounted between glass at Ghizeh, and is the finest piece of ancient woodwork in the collection.

Both this season and the last many hundreds of blocks have been recovered, sculptured with the Queen's exploits, her wars and the transportation of her obelisks from Syene. So long buried, the coloring of these scenes is as vivid as their execution is admira-

BREASTPLATE OF USERTASEN III

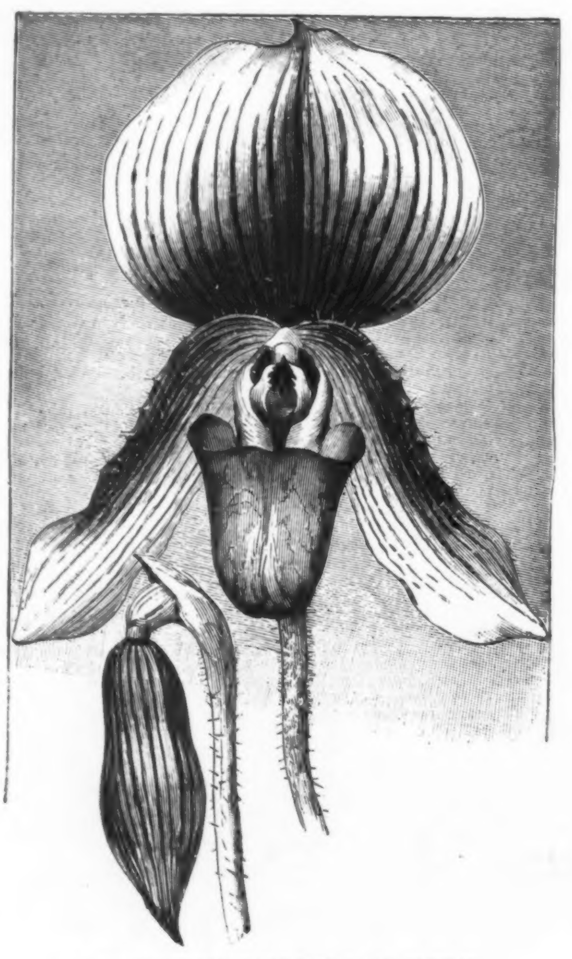
ble, and they will bear comparison with any work of the 18th and 19th Dynasties, even that of Seti I. at Abydos. During the past winter the middle terrace also has been cleared in great part. A fine colonnade, a hypostyle hall with brilliant paintings and a portico adorned with scenes relating to the Queen's birth have been opened once more to the light of day. The portico reliefs have a peculiar interest as being apparently originals of the famous scenes in the temple of Amenhotep III. at Luxor, in which his birth by an immortal father is portrayed. In clearing so large a space many small things must always be found, and in this instance there has been a large find of *ostraka*, hieratic, demotic and Coptic, of blue scarabs and amulets of the famous local ware. The work is to be resumed next season, and when all is done the Egypt Exploration Fund will have the credit of having restored to the world one of the most singular and beautiful monuments of antiquity.

Thirty miles lower down the river Mr. Flinders Petrie has met with his usual success at Kuft, the site of ancient Coptos. His marvelous instinct of discovery led him to select the temple site, which lies in the midst of the Roman city, and, turning over the *débris* from end to end, he has found most interesting remains of the worship of Khem in all periods. In the foundation sand of the Ptolemaic restoration he lighted on three *colossi* of the god, so strange and rude in style that he supposes them to be almost prehistoric, the work of the first immigrants from Arabia before Mena founded the 1st Dynasty. Carved on them in low relief are symbols, shells and animals, whose style may help to fix their period. A lively discussion is likely to arise, and we may expect to hear them referred to every date from that of the Arabian immigration to the occupation of Coptos by the Blemmyes after our era. Other finds of Mr. Petrie's, however, go back far enough; a fragment of alabaster bore the cartouche of Khufu of the 4th Dynasty, and slabs of a pavement of Thothmes III. showed on their reverse sides scenes from the temple of the 11th Dynasty, unfortunately very imperfect, for they are the earliest temple sculptures known. A door jamb was carved with the finest work of Usertasen I. of the 12th Dynasty. Foundation deposits of the 18th, a triad and *stelæ* of the Ramesside period, pottery of all the dynasties from before the pyramid builders to the Roman, make up with many odds and ends a find equal in interest to any that Mr. Petrie has ever made, except, perhaps, at Naucratis. We may mention also that a remarkable Roman inscription was found at Kuft shortly before Mr. Petrie's arrival, giving a list of tolls to be paid at the Red Sea gate of Coptos.

A very important symptom of the past season has been the awakening of interest in ancient Alexandria, and we shall probably hear a great deal about the Ptolemaic and Roman capital in the future. It is the most unexplored site in Egypt, and it is really astounding that we should know so little of what was once the first city (and has always been among the first) on the Mediterranean. The meeting place of so many races, bound up with Jewish and early Christian history, an unrivaled center of culture, the burial place of the greatest of ancient conquerors and of a long line of his successors, the most singular and favored city in the Roman empire, Alexandria has limitless possibilities. The ancient city lies deep under the modern; but, now that the municipality is favorable, the new museum has been organized, and persons of local influence are at work, we may hope that an exploration has been begun which will prove of extraordinary interest, if carried through.

Odds and ends of work there have been many. The beautiful temple of Kom Ombo has been rescued by M. De Morgan from the wash of the Nile, and albeit a little too thoroughly swept and garnished, presents a very fine appearance. Members of the French mission have copied its inscriptions throughout, and the plates will appear shortly in the publication of "Unedited Monuments," promoted by the Director-General. Mr. Sayce has been exploring Nubia and finding forts and *graffiti* and *stelæ*, whereof he has given account in the pages of the *Academy*. Dr. Hess has been searching the same shores for demotic texts, but the result of his labors is not known. Captain Lyons, R.E., has brought back much information and some antiquities of note from the Oases, and Mr. Bloundell is about to explore the Temple of Ammon at Siwah in the course of a wild and difficult journey which he hopes to terminate in the Cyrenaica. Messrs. Tyler and Somers Clarke are continuing their work at El Kab.

* The total number of pieces in gold found in this tomb was 165, besides 240 beads of amethyst, 70 beads of emerald, *lapis lazuli*, and carnelian, and a larger number of smaller beads of various precious stones. The total weight of gold pieces found was 314⅛ grammes.



CYPRIPEDIUM CALLOSUM SANDERÆ.

CYPRIPEDIUM CALLOSUM SANDERÆ.

A MOST interesting and valuable novelty, being the nearest approach to an albino yet found of this species. The habit and size of flower is identical with the type, but the color is vastly different. The large, broad dorsal sepal is of the purest white, beautifully lined and veined with lovely emerald green. The curved petals have a ground color of pale yellowish green, the lower halves (horizontally) and also the apices are pure white. The lip is apple green, large and pointed; the flower stands up well. F.C.C., R.H.S., May 23. Messrs. F. Sander & Co.—*The Gardeners' Magazine.*

LICORICE.

(*Glycyrrhiza glabra*, L.)

IN consequence of the large quantities of licorice root now exported from Asia Minor and other licorice-growing countries to America, where it is used in the preparation of tobacco for chewing purposes, and also in making a fancy drink, a considerable amount of attention has been given to the introduction of the plant in India, America, and other countries where it is at all likely to thrive.

The licorice plant (*Glycyrrhiza glabra*, L.) is a native of North Africa, Southern Europe, Syria, Persia, and Afghanistan, and is cultivated in France, Russia, Germany, Spain, and China, and also to a slight extent in England, where its growth is said to date from the middle of the sixteenth century. Some twenty or thirty years ago licorice was cultivated in market gardens in the neighborhood of London, especially about Kew and Isleworth, and more recently at Mitcham. At the present time Yorkshire produces the larger quantity of English-grown root, and the principal seat of its culture is in and around Pontefract. Its cultivation in this particular neighborhood dates back several generations, the deep, rich, loamy soil which occurs here being specially suited to the growth of the plant. The bulk of the licorice gardens are situated on the fertile slopes east and northeast of the town, the country between Pontefract and Knottingly being largely occupied by market gardens, in which licorice forms an extensive crop. The following notes on the cultivation of the plant and harvesting the root are taken from an article on the "Culture and Preparation of Licorice," which appeared in the *Leisure Hour* for April, 1893:

"The plants are grown in rows, and they stand from three to four years before arriving at perfection. The three years' growth is thinner and scarcely so rich in juice as the four years' plants. Occasionally, if the market is flat, the plants are allowed to grow a fifth season, but the root becomes thicker, coarser, and more woody. The long, straight root goes down to a great depth, averaging perhaps about four feet, but sometimes even to six feet, and as the soil has to be dug down to this depth by hand to extract the root, the labor of cropping or harvesting is considerable. During the first two years that the land is occupied by licorice, the plants themselves being small allow of other crops being planted between the rows, and potatoes, and different varieties of cabbage, are mostly grown. The ground being earthed up around the licorice plants, the furrows thus made afford much protection to the vegetable crops, and, as the ground is always richly manured before planting licorice, favorable conditions are thus insured for the production of early and very superior vegetables; indeed, it is said that the vegetable crops from a licorice plantation always command high prices in the Leeds markets. After the second year, however, the licorice plants grow to such a height, and spread their foliage so widely, that other crops will not grow beneath them. On a visit to Pontefract, namely, in the early part of September, the writer saw some of these licorice gardens where the plants had attained the age of five years and a height of about four feet, each plant sending up numerous straight stout stems from the rootstock or crown, each stem bearing large spreading alternate leaves, composed of a number of opposite leaflets of a bright green color.

"The harvesting season is about the middle of September, and after the roots have been taken out of the ground by hand digging, as before mentioned, they are stored in cool ventilated houses or cellars, usually in sand, until a favorable opportunity occurs for the process of dressing, which consists of trimming off all the fibrous rootlets, buds, and runners, or stolons. The fibrous roots are ground into licorice powder, which is used as a medicine, and the buds and runners are carefully preserved in sand for planting, for it is from these alone that new plants are raised, and never from seed. The plants never being allowed to flower, do not, of course, produced seed. Flowering would deteriorate the value of the plant from a commercial point of

view, as the juices would be consumed in perfecting the flowers, and the roots thus become useless. The planting of buds and runners for a new crop is done in the early part of April."

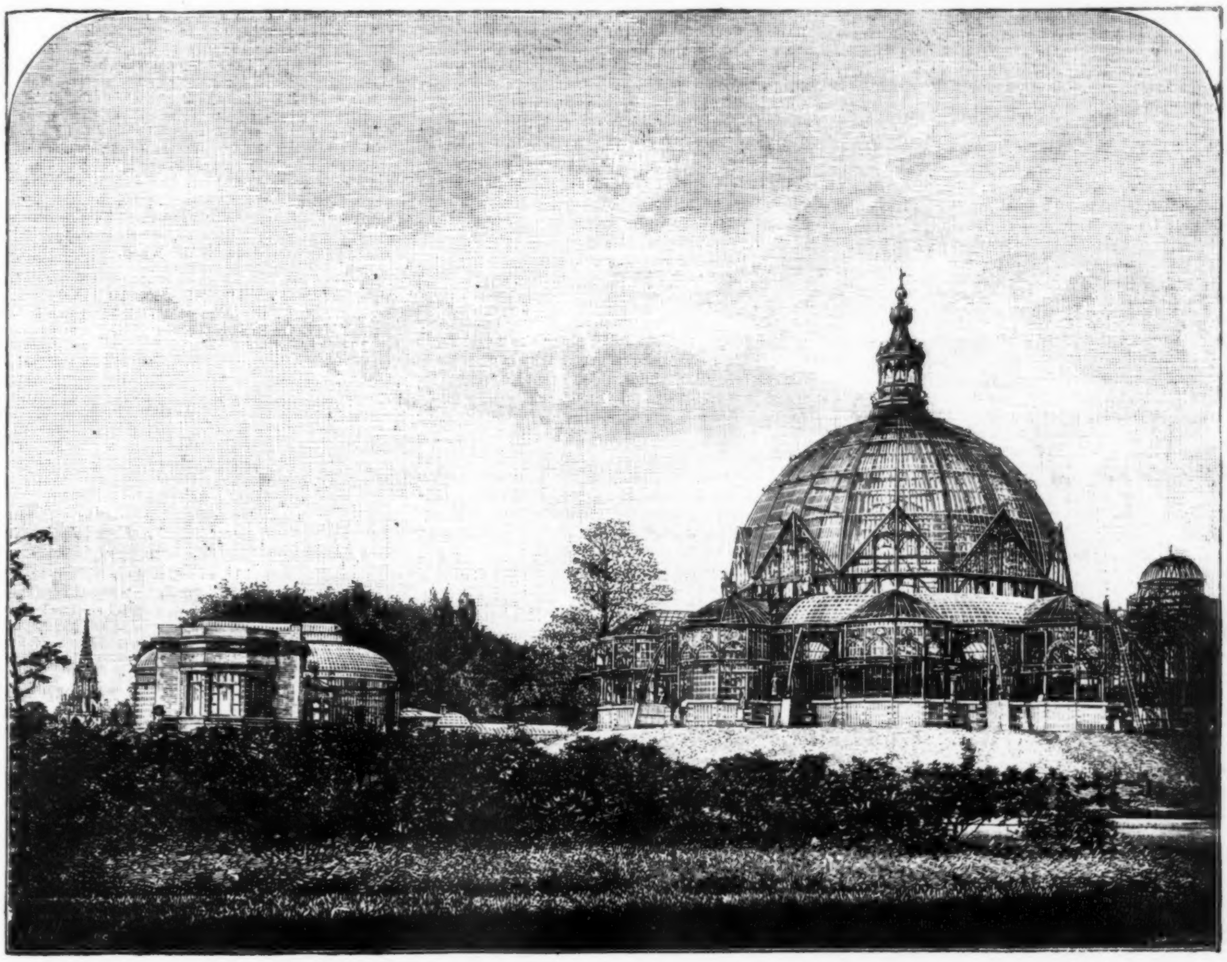
In Bentley and Trimen's *Medicinal Plants*, vol. ii., under plate 74, it is stated that "both Spanish and Russian licorice roots are usually imported in bales or bundles, or, rarely, in the case of that portion of the Spanish variety which is derived from Alicante, loose or in bags. The Spanish licorice root is in straight, unpeeled pieces, several feet in length, and varying in thickness from a quarter of an inch to about one inch. That from Alicante is frequently untrimmed and dirty in appearance, but that from Tortosa is usually clean and brighter looking. The Russian licorice root, which is imported from Hamburg, is either peeled or unpeeled. It is in pieces varying from twelve to eighteen inches in length, and from a quarter of an inch to an inch or more in diameter. Combined with the usual sweetness of licorice root, this variety has a feebly bitter taste."—*Kew Bulletin.*

CONSERVATORY CHAPEL AT LAEKEN.

IN the grounds of the Palace of His Majesty the King of the Belgians, on high ground, with the lake beneath, and with the opposite bank richly clad with flowering shrubs, capped by the picturesque old windmill, which visiting artists always admire, stands the recently finished conservatory chapel, planned by His Majesty, and which, while being a novelty in its way, is a beautiful one. Wholly built of glass and ornamental iron-work, it is externally, and by its arrangement internally, in the nature of a gigantic conservatory, the only evidence of its being consecrated to divine service being the altar piece, which faces the entrance, and a few other less conspicuous objects. The width from the entrance to the altar on the opposite side is about 140 feet; the height of the dome 100 feet. The space beneath the dome has a mosaic floor, on which chairs are placed, leaving a walk up the middle. The dome is supported by ten pairs of polished red granite pillars on white pediments, and around each pair a space is laid out with tile edging, in which tall palms and tree ferns are planted, faced by flowering plants, which are removed as they go out of bloom, and are replaced by others in flower. Around the space beneath the dome is a circular walk, 20 feet in width, and beneath which the pipes for heating the structure are laid. On the outer side of the walk, and bordering the building, provision is made all around for palms and flowers, and lofty alcoves are arranged, in the front of each of which a white marble statue is placed, the alcove behind being filled with lofty palms and other foliage and flowering plants, some of which are permanent, and the others removable. It is altogether a beautiful structure, and artistically arranged, and one in which the hand of time will evolve still greater beauties, as the plants grow and adapt themselves to the positions in which they are placed. It is scarcely necessary to say that it is lighted by electric light, in the same way as the miles of the flower-planted corridors which connect all the conservatory-like buildings, in which state functions are held, the great palm houses, the orangery, etc.

Descending the steps at the side, and under the guidance of Mr. Knight, who has charge of the vast domain, we proceed to note a few of the more striking features in the gardens as we pass. On the steps are vases filled with flowering plants, and on the roof the flowers of varieties of Tropæolum Lobbianum and of Pelargonium peltatum. At the bottom is a fine group, in which the center consisted at the time we write about of a grand plant of Cattelya Trianæi, with about sixty open flowers. Passing along the corridor, we remark the numerous plants of the useful Coronilla glauca, which are trained over the roof, and which it is intended to plant more extensively. Arriving at the first tropical house, filled with giant Pandanus, Pritchardia pacifica, and other species of palms, tree ferns, Bromeliads, and many large baskets suspended from the roof filled with grand plants of Goniophlebium subauriculatum, with fronds ten to twelve feet long, we continue along the corridors, the principal plants in flower in which were quantites of Cliantbus puniceus, Tacsonias, and other climbers, and then we come to the great azalea house, a blaze of bloom in the season, with the flowers of the fine specimens of Azalea indica varieties, but brightened by the soft yellow, salmon, and red tints of the Azalea mollis, and the fragrant mignonette, which is grown remarkably well at Laeken. Continuing along the corridors, in this part brilliant with the bright trusses of some of the scarlet pelargoniums, which adapt themselves for training, we come to the orchid houses, where only showy species are grown, useful for cutting or decoration. In the next stretch of covered way the fuchsias depending from the roof and clothing the sides are very effective, and the heliotropes both pretty and fragrant. Here, too, Brugmansia sanguinea is covered with large flowers.

Descending the steps to reach the tunnel, here necessary to cross the roadway, we remark the fine effect of the standard Polygalas and Genistas. The board steps leading to the fine winter garden, palm house, and orangery, often alluded to in these pages, have a very pretty show of flowers, among which were some very effective orchids. Overhead were suspended large masses of Oncidium pulvinatum, with their long, pendent sprays of yellow flowers. Around the great palm house the planted out specimens of Euphorbia jacquinæflora are perfectly charming, arching their pretty sprays of vermilion flowers over the side of the walk, each plant having twenty to thirty sprays, some of them with nearly two feet length of flower at their tips. Vases of Cattleyas and Cypripediums, too, give bright color, and the fine old palms are indescribably stately and picturesque in this gigantic structure, whose dome, supported by enormous white pillars, is about 140 feet in height. The orangery, with its rows of huge specimens, beautiful in the subdued light; the magnificent camellia house, filled with flowers; and the good show of greenhouse rhododendrons, were in that perfect order in which Mr. Knight keeps everything in this great garden. His office is no sinecure, for some hundred and forty regular men are employed under him, and the extent of the work under glass alone may be estimated when it said that in a single year over £3,000 has been spent in fuel to heat the structures alone.—*The Gardeners' Chronicle.*



THE CONSERVATORY CHAPEL AT LAEKEN.

THE Spanish peasant works every day and dances half the night, and yet eats only his black bread, onion and watermelon. The Smyrna porter eats only a little fruit and some olives, yet he carries with ease his load of two hundred pounds.

THE GEOLOGICAL DEVELOPMENT OF THE UNITED STATES.

By RALPH S. TARR.

A STUDY of the fossils, and of the rocks themselves, has given geologists a basis for a chronology; and the history of the earth is, therefore, divided into periods which do not mean periods of time, but periods in the life history of the planet. Thus the Archean does not represent a period of years, but a period including those rocks which were laid down before the oldest known fossiliferous rocks. The Paleozoic, divided into Cimbrian, Silurian, Devonian and Carboniferous, includes fossiliferous rocks which have certain definite fossils; and coming down toward the present, we have the Jura-Trias and Cretaceous as divisions of the Mesozoic, and Tertiary and Quaternary as divisions of the Cenozoic. Different text books adopt different names, but these are the ones used in this article. They cover a time incalculably long, amounting probably to millions of years; and from their pages the geologist is able to read a story with here and there a missing page, but with a sufficiently continuous record to enable him to place a correct interpretation upon the events of most importance in the history of the earth.

What the conditions were in this country during the earliest ages is only partly known. We believe that the planet was once a part of a nebula, and that it has assumed its present form by loss of heat and consequent solidification. Indeed, many of the changes of the past and present are apparently due to the continued loss of heat and contraction of a globe still hot within. The earth must have first of all become liquid and then solid. We have no determined signs of the original crust of the earth, though some hold that the rocks of Archean age, the granitic gneisses of Canada and New England, are a part of this original crust. If this be the case, we have not yet learned to discover from these rocks any facts concerning the early history of the globe.

When we come down to the beginning of the Paleozoic, the time when the first well defined signs of life appear in the rocks, our history is more perfect. Just as the history of man becomes more and more obscure as we go backward from the present, so the history of the earth is more dimly recorded in early ages than at present. We have not yet learned whether life existed on the earth before the Paleozoic. Some have argued that the presence of graphite, phosphate deposits, limestone and iron, are of themselves proofs that there were organisms in the Archean. These are not, however, necessarily proofs of this, but are mere suggestions; for all of these may have been formed in a different way. Supposed evidences of fossils have been recorded from these rocks, some of them being apparently valid, others without foundation. To my mind, the strong argument in favor of the existence of Archean life is the fact that at the beginning of the Paleozoic there appears in the rocks a great assemblage of fossil forms. Ever since then these forms have been widening in development, and it seems fair to believe that they had done so before the Paleozoic. Still, the Archean reveals to us no definite evidence of organic life in variety. It is true that such signs would hardly be expected in these old rocks, which have been so altered that even their original character is masked, and from which it would seem

probable that all delicate organisms would be removed.

Concerning the physical geography of the Archean times in this country, we have a little more knowledge. The continent of North America seems to have been thus early outlined. There was in Canada a great land area, probably rising in mountainous heights, the remnants of which are seen in Labrador, central Canada and northern Canada. Along the present site of our western Cordilleras there appears to have been an archipelago, the Canadian land extended into the United States near Lake Superior, and there was an area extending from New England southwestward, along the eastern flank of the present Appalachians, down into the Southern States. The Adirondacks formed a land area, perhaps an island. How far eastward into the Atlantic this eastern mountain area extended we cannot say, but it certainly extended some distance. Nor are we able to estimate the height of the mountains; but all things appear to indicate that they were very high.

Where now is located the central plain of the United States, that is the Mississippi Valley, there was a great inland sea; but its shore lines are not traceable in all places. It impinged upon parts of the Cordilleran Archipelago, the Canadian Highlands, the Adirondacks and the Highlands of New Jersey. Connecting these points, it seems probable that we would have a rough idea of the shape of the inland sea; but the form and extent of the inclosing land areas may only be guessed. One fact brought out in several places is that there was a soil on the Archean land, derived from the disintegration of the rocks, just as is the case at present in the Southern States and in most southerly temperate and tropical latitudes. We are not without indication also that there was abundant volcanic activity in Archean times. The conditions, therefore, appear to have been in many respects like the present, although the physical geography was very different.

Along the margin of this land the early Paleozoic sediments, the Cambrian, were accumulated. The two great depressions of the land to-day, the Mississippi and the St. Lawrence valleys, were submerged, having their present condition thus early outlined, just as the present highlands were then outlined. In the mountains of the East, early Paleozoic eruptions occurred and volcanoes existed in many places, among others near Boston and in Maryland. We find to-day the lavas that flowed out in those times, and the volcanic ash that was thrown into the air. The volcanic cones have long since wasted away, as indeed have the very mountains themselves, and we have only here and there fragmentary records of these early Paleozoic volcanic episodes.

During nearly all of the Paleozoic, that is, through the long ages of the Cambrian, the Silurian, the Devonian and a part of the Carboniferous, the interior sea maintained its existence and was the gathering ground for the waste from the inclosing mountainous lands. Many thousands of feet of rocks, sandstones, shales, conglomerates and limestones were deposited in this sea, which slowly subsided as the sediments accumulated. Here were then formed the stores of building stones which we are now using, just as similar rocks are forming in existing oceans. For the gathering together of these quantities of rocks ages to be measured in hundreds of thousands of years must have elapsed.

Where now the Appalachians are situated there was then a shore line with a land area extending eastward beyond the present coast line. Large rivers entered the Mississippi sea, adding to the ocean bottom the sediments which they bore. The climate was then more equable than now, and there existed in favorable places, just as in the Bermudas of to-day, reefs of coral, which are now fossilized in some of the limestone beds. A warm current appears to have circulated in this interior sea, and different geologists have postulated a great Sargassum Sea in the swirl of this current. In this way attempts have been made to account for the bituminous shales of Kentucky, and also for the zinc-lead deposits of Missouri and neighboring States, the idea being that the constant decay of the floating seaweed in one case furnished carbonaceous matter, in the other disseminated lead and zinc, which were later gathered together just as flint in chalk is gathered into nodules, from a disseminated state, by a process of segregation or concretion.

Toward the close of the Paleozoic, that is in the Carboniferous time, the beginning of the Appalachians and central plains was made by an elevation, which transformed this part of the inland sea into a shallow water and marshy land. Here the coal vegetation grew, and we owe to this condition the supply of fuel upon which we are now depending. The conditions at this time were very peculiar, but we cannot at this time enter into their consideration. Suffice it to state that a luxuriant vegetation, resembling the present tropical flora, in many characteristics, grew upon a swampy land, perhaps upon a salt water swamp. The temperature was more equable than now, the moisture apparently greater and the land in an unstable condition. The latter point is indicated by the fact that coal beds were formed and then covered with marine sediments, upon which other coal-producing forests were accumulated. That is, there was an alternation of land and ocean several times repeated.

Immediately following this condition, which may be considered a premonition of what was to follow, came the formation of the Appalachian in the Permian period and the formation of the plains of the central States. Since that time these areas have been dry land continuously and the eastern part of the country was practically finished except for slight additions to the east coast and extensive erosion and sculpturing of the land areas into the present hills and valleys.

Elsewhere in the United States the Permian appears to have been a period of dryness. In at least one place, Texas, and perhaps elsewhere, as in Kansas, there existed in this period a condition of interior salt seas which eventually became dead seas. The red beds of central Texas, with their accompanying deposits of salt and gypsum, were formed during this time.

In the next period, which we may call the Jura-Trias, combining two periods, as recognized in Europe, there came in the East the last period of volcanic activity, while in the West the Sierra Nevadas were formed into high mountains. The volcanic activity of the East was expressed along the entire Atlantic seaboard, from the Carolinas to Nova Scotia, by a series of intensions of a black trap rock and by volcanoes from which the same black basaltic lava flowed in great sheets. These intruded and extruded lavas still exist in remnants, and where they occur have produced striking features in the present topography. Among the more striking instances of this are the Palisades of the Hudson, the trap hills of Paterson and Orange, New Jersey, East and West Rocks of New Haven, Connecticut, Mts. Holyoke, Tom, the Hanging Hills of Meriden, and other prominent hills of the Connecticut Valley, etc. Since then there has been no volcanic action in the East. During the Jura-Trias there was an estuary where now the Connecticut Valley is situated and ocean waters extended as far northward as Northfield, Mass. The Atlantic coast was farther west than now and the waters of the ocean nearly bathed the eastern foot of the Appalachians.

During the Cretaceous period, which followed, the eastern coast of the country seems to have been nearly of the present form, although many of the finishing touches were wanting; but the western part of the country was very different from the present. A great arm of the sea extended, along the site of the present Rockies and the plateau of their eastern base, from the Gulf far northward into Canada. At times, and perhaps always during this period, there existed islands in this sea, but the main feature was that of water. Neither the Rockies nor the Coast Ranges existed then, and the Sierra Nevadas were bathed upon both their eastern and western bases by oceanic waters. Florida, Arkansas, Alabama and Texas were mostly beneath water, and here the sediments that were later built into these lands were accumulated.

At the close of the Cretaceous, much of this area was permanently transformed into land and the Rockies began to be formed. There was added to the east coast a strip of land, widening toward the south, and at present forming the inner or western part of the plains which lie between the Appalachians and the ocean. Florida was not formed and the low swampy plains from New Jersey southward were still beneath the ocean. An arm of the sea extended up the Mississippi Valley and the site of the Rocky Mountains and the present interior basin was occupied by a land dotted by many very large fresh water lakes.

The Tertiary period witnessed many interesting changes, which, being recent, are much more plainly recorded than those of earlier periods. In the East the land was much higher than the present. There are indications, in the existence of apparent river channels on the ocean bottom, that the coast line was then at the edge of the continental shelf, or from 75 to 100 miles farther seaward in our latitude. During the Tertiary, portions of the coastal plains were added to the east coast and Florida was formed partly by elevation and partly by the outward growth of the land, through the agency of reef-building corals.

The most stupendous event of this period, however, was the development of the Rocky Mountains. By these rock folds great lakes were destroyed and their sediments incorporated into the growing mountains, and other lake basins were formed, some of which have been destroyed and others of which remain. Most of these, owing to the aridity of the climate, are either dry, as in the case of the great continental basin, or are occupied by salt lakes, such as the Great Salt Lake. Immense flows of lava, destructive volcanoes, and intrusions of igneous rock accompanied this folding and faulting of the rocks, and we find in the West no more common phenomenon than that of partially destroyed volcanic cones and lava flows. They exist throughout the entire Cordilleras, from the eastern flank of the Rockies to the Pacific and from the Mexican boundary to Canada.

As a result of these changes we owe the formation of the wonderful mineral deposits of the West, while in the lakes there were formed vast stores of salt, gypsum, coal and other products. This, which is the most marvelous mineral region known in the world, owes its richness in this respect to its complicated history of folding, faulting, and volcanic eruption. For the present the Rockies seem to have nearly ceased growing, although there are many signs that the growth has not entirely ceased. Within extremely recent times, though not within the history of man, there have been volcanic eruptions, and recently formed lake shore lines have been tilted out of position. As one of the episodes of the Tertiary there was a regrowth of the Sierras and the formation of the Coast Ranges. This seems to have been a part of the great movements which produced the Rockies, but to have been somewhat more recent and, indeed, to be even now in progress of development.

In the Quaternary period one event of great importance occurred, as well as numerous minor changes. The land appears to have fallen and then risen again, and the finishing touches of the present land were made. A narrow coastal addition was made, particularly on the Gulf coast, where the Mississippi embayment was destroyed by the growth of the delta and the uplift of the land. On other parts of this coast low-lying swampy plains were also added.

A series of minor events occurred in the Cordilleras. Volcanic activity continued with constantly decreasing violence, the folding of the mountains approached its close and erosion made extensive breaches in the high mountains. The climate also suffered a change and the interior basin was changed from an arid to a moist region, then again arid and moist, followed by the present condition of aridity. During one of the moist periods great lakes existed in the present interior deserts and overflowed to the sea.

But by far the most important episode of the Quaternary was the oncoming of the glacial period, which followed closely upon the condition of high Tertiary elevation. Extending down to the latitude of New York this ice sheet transformed the northern part of the continent to a great ice plateau analogous to the present Greenland ice cap. How long it stayed and what its exact history has been are points that are still unsettled and under investigation. We know considerable about its effects, and it has been responsible for the great majority of the minor topographic features of the glaciated belt. Our soils and clays, lakes and waterfalls and many interesting bits of scenery are due to this ice invasion, and even the harbors of the New England coast appear to be indirectly a result of the ice period.

To quote the last words of a paragraph upon the same subject in a recent work by the author,* "This is, briefly, and without entering into details or proofs, the general evolution of the continent. Its form was roughly sketched in the very earliest period and it has been slowly perfected, although undoubtedly many changes yet await it. No adequate mention has been made of the effect of erosion during all this time, but this is of prime importance. Old lands have been worn down, and the ruins deposited in the water, to afterward be again built into land and perhaps again transformed into sediment. Erosion and sculpturing have been ever acting, and the present form of the continent is the resultant of the conflict between the two opposing forces; the one tending to build up, the other to tear down."

* "Economic Geology of the United States."

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